JULY 1940

OUR WORK IN PUERTO RICO

SOIL CONSERVATION

OFFICIAL ORGAN OF THE SOIL CONSERVATION SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE WASHINGTON

Contents

Covers by Helen Morley

WELLINGTON BRINK
EDITOR

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A jibaro and his pony come down the path to market from a mountain home. This tableau is enacted thousands of times any fair morning in Puerto Rico.

In one hand the jibaro holds a chicken. Berengenas—egg plants—hang from the farmer's neck. In the basket on the pony's back are bananas, turnips, more egg plants, a sampling of an amazing variety of foodstuffs.

The native pony has an aristocratic ancestry. His forebears were Arabians, introduced by the Spaniards upon discovery of Puerto Rico by Columbus four centuries ago. The Arabian stock had been brought by way of Andalucia to Puerto Rico.

The mountaineer's pony is gentle, and of great endurance. All he asks of his master at the end of a day of carrying heavy loads up and down rugged paths is to be turned loose through the night so that he may eat grass, drink water, and rest himself for another day of faithful service.

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Seeking the answers to slope farming

1 Contour ditches built in a natural pasture help to conserve rainfall.

2 Run-off plots, Las Ochenta, Mayaguez area.

3 Bench terrace outlet channel.

4 Rock barriers being thrown up near Arroyo, on P. R. R. A. resettlers' land.

5 Research with various grasses. Object: To discover the sodding qualities and the optimum degree of bank slopes. These bench terraces are at Mayaguez.

SOIL CONSERVATION

HENRY A. WALLACE
Secretary of Agriculture

HUGH H. BENNETT
Chief, Soil Conservation Service

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SOIL CONSERVATION PROGRAM IN PUERTO RICO

By G. L. CRAWFORD [1]

IN 1935 SOIL CONSERVATION SERVICE employees made a reconnaissance erosion survey in Puerto Rico and located problem areas. Through the cooperative efforts of the Puerto Rico Reconstruction Administration (commonly called the "P. R. R. A."), the Puerto Rican Experiment Station of the United States Department of Agriculture at Mayaguez and the Forestry Service, the soil conservation camp at Las Mesas, near Mayaguez, was set up and began work with a corps of 200 men in September 1936. The men were employed in constructing bench terraces with simple hand tools on land having an average slope of 35 percent.

During a period of experimentation, while the type of bench terrace suited to Puerto Rico was being developed, the organization plans for an island-wide soil conservation program were outlined. The program was developed through conferences and contacts with interested people, and its final crystalization and the job of putting it into practice were realized largely through the assistance of the Soil Conservation Advisory Committee. From the beginning, this committee has been composed of the heads of the following organizations: Agricultural Extension Service, Department of Agriculture and Commerce, Rural Rehabilitation Division of the Puerto Rico Reconstruction Administration, insular and Federal experiment stations, Agricultural Adjustment Administration, United States Forest Service, College of Agriculture and Mechanic Arts, and Soil Conservation Service.

It was decided that an agricultural engineer, and an agronomist well trained in soil conservation methods, should be placed at each soil conservation area. Two soils specialists were to be located at the headquarters' office, with the understanding that their activities cover the island. Additional funds were supplied through the cooperation of the P. R. R. A. and 20 local college graduates trained in engineering, agronomy, and soils were employed. Such, in brief, is the genesis of the general plan for operations that has been followed until the present time.

Gradually, through the increase of funds allotted by the P. R. R. A. for soil conservation work, it has been possible to add to the organization's personnel and to spread the Soil Conservation Service personnel over the island. At present, about 60 local technical men are employed and about 1,500 skilled, semiskilled, and unskilled laborers. Each Soil Conservation Service technician is supervising from two to four areas.

[1] In charge, Soil Conservation Service, U. S. Department of Agriculture, Puerto Rico and Virgin Islands.

On March 1937, plans were completed for a soil conservation experiment station to be located at Mayaguez on Federal land occupied by the Puerto Rico Experiment Station of the United States Department of Agriculture. The work was to be carried on in cooperation with the director. On January 1938, another soil conservation experiment station was started at Rio Piedras, on insular land occupied by the Agricultural Experiment Station of the University of Puerto Rico, and in cooperation with the director.

Careful estimates show that 40 percent or more of the arable land of Puerto Rico has a slope of 40 percent or greater. The population amounts to more than 500 people per square mile, and about 80 percent of them depend directly or indirectly upon agriculture for a livelihood. In view of this it is apparent that an adequate soil conservation program in Puerto Rico must embrace the successful control of erosion and conservation of moisture on steep mountainsides. Therefore, the first important problems to be outlined at the Mayaguez station included the control of bench terrace banks. After the proper slope of the bank was determined, and the type of grass best adapted for bank cover, an experiment was started for the specific purpose of finding a food crop that could be grown on these banks in place of the grass cover. This experiment is still in progress.

Another important feature of the research program for this station is that involving the development of a cheaper method of building bench terraces than the hand construction method. Experimentation along this line has resulted in the vegetative barrier method —stiff upright-growing plants are planted on the contour or a slight grade at intervals of from 3 to 8 feet on the mountainsides. By the normal process of preparing land and cultivating crops, a bench terrace is formed in 3 to 5 years.

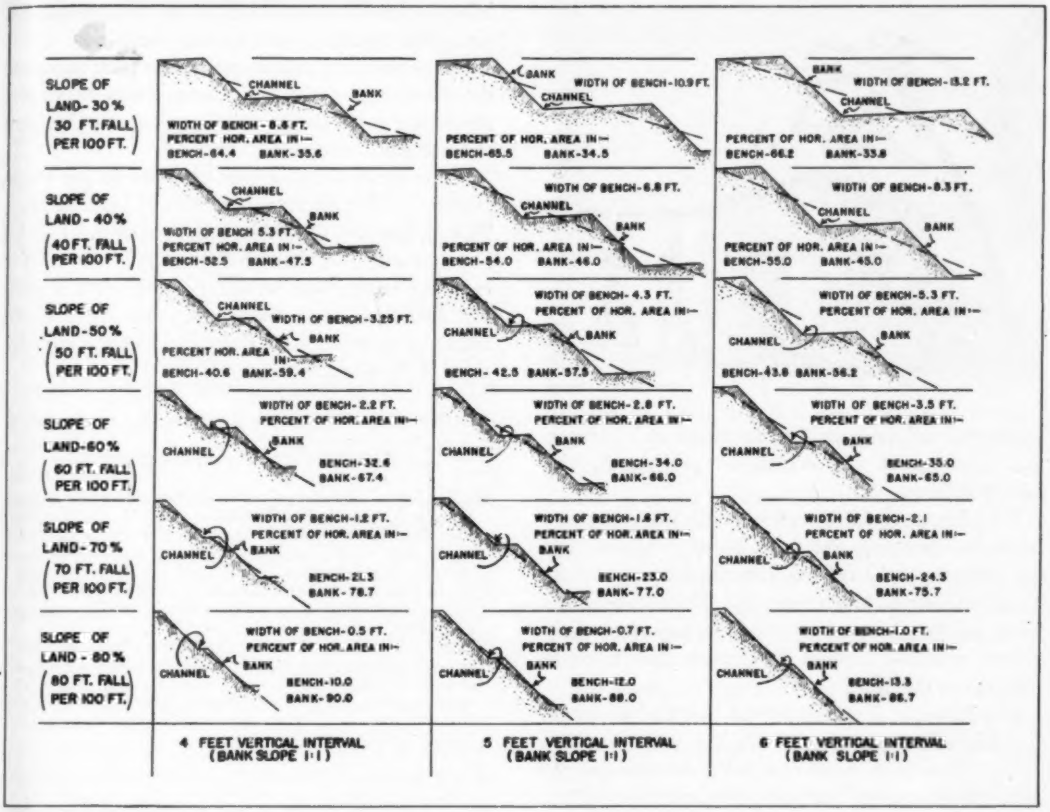
These are two of the major problems which the Mayaguez station has been working on during the past 3 years. In addition, projects are being carried out to determine the relative values of different types of vegetation, and to estimate the erodibility of fallow land and subsoil through the use of run-off measuring plots.

As it was generally recognized that grasses play a tremendous part in soil conservation, the Rio Piedras Agricultural Experiment Station turned over to the Soil Conservation Station the plots of ground on which they had been working with grasses. These plots have been increased until at present the Soil Conservation Experiment Station has more than two hundred $\frac{1}{100}$-acre plots. The Soil Conservation Service is not only making detailed studies of the root systems, crown and growth characteristics of the grasses, but also is cooperating with the Insular Experiment Station and the School of Tropical Medicine in making analyses of the grasses as to their nutritional value. Digestive tests will be made on some of the plants this year. In addition, the Rio Piedras station is carrying on a cooperative experiment with the Insular Experiment Station in studying the erodibility of soils as related to their chemical and physical properties. These tests, in turn, are being made on the soils of the run-off plots at Mayaguez.

The operations program, as previously indicated, deals necessarily with slopes, many of which are very steep. The soil conservation surveys in Puerto Rico indicate not only the type of soil, extent of erosion and degree of slope, but also the depth to rock. This is of vital importance to the engineer in determining the kind of structure to be installed on each particular slope. For example, if the depth to rock is 4 feet, it is possible to plant barriers at a vertical interval of 5 feet and build a bench terrace in 3 to 5 years without exposing rock. On the other hand, if the survey indicates that the rock is within 15 inches of the surface, it is impractical to build bench terraces, and some other structure must be installed on the field. The engineering problems are many when it comes to developing a land-use program on the mountainous soils of Puerto Rico. The steeper the slope, the narrower will be the bench—with a vertical interval of 4 feet and a slope of 30 percent, the bench will be about 8½ feet wide; but if the slope is 70 percent, other things being equal the bench will be about 1 foot wide.

As for the agronomist's problems, he not only must establish vegetation in outlet channels for permanent use and service at the minimum upkeep, on slopes up to 70 percent, but he must be on the lookout constantly for new methods of placing vegetation in these outlets, as the work is rather expensive and the best-known materials are scarce. The Soil Conservation Service agronomists in Puerto Rico have been called on by other agencies, such as the Insular Highway Department, to assist in establishing vegetation on steep slopes. Technicians of the Soil Conservation Service in Puerto Rico face new problems at almost every turn; to date they have had about 3 years' experience working with small farmers on the island.

About two thousand resettlers' farms have been developed according to soil conservation methods. An agreement was entered into between the farm superintendent in the resettlers' area, the farmer, the



agricultural extension agent, and a representative of the Soil Conservation Service, and from the agreement a 5-year program has been set up. In many instances farmers are now deriving a subsistence living from their farms. The small farmers in the mountain areas are being offered an opportunity to cooperate in a soil conservation program. This includes not only structures, such as hillside ditches and contour cultivation, but also a crop rotation plan to supply adequate food for the family and add humus to the soil for gradual increase of its productiveness. Also the farmer is being given several months' work under the supervision of a personnel trained in soil-conservation methods. This program is supplying him with funds while he develops his farm for a greater production.

The Soil Conservation Service is now working in 4 areas with about 500 private farms. More than 85 percent of these farmers have entered into a contract with the P. R. R. A. to cooperate in the soil conservation program. It is expected that at least 95 percent of the farmers in each area will cooperate in the program before the work is completed. This indicates a good attitude on the part of the small farmers of the island toward an agency trying to assist them to become economically independent.

The soil conservation program in Puerto Rico would be much more difficult than it is were it not for the splendid cooperation and friendly assistance received from other agencies on the island. The P. R. R. A. not only has assisted the program by supplying funds but has offered encouragement whenever possible.

The Commissioner of Agriculture and Commerce has been for a long time a strong supporter of the soil conservation idea. He started a research project in soil conservation at the Rio Piedras station a number of years ago.

The University of Puerto Rico Agricultural Experiment Station at Rio Piedras is cooperating by supplying office space and land, and in developing a cooperative project for the study of the erodibility of Puerto Rican soils according to soil types.

The Federal experiment station at Mayaguez has fostered the work from its inception, not only by giving timely advice but also by supplying office space, land, and other valuable assistance.

The Forestry Service, both Federal and insular, has

cooperated fully in supplying assistance and aiding in the development of cooperative projects in the National Forest.

The Director of the Extension Service has spent many hours in inspecting soil conservation practices, and has encouraged the extension staff and county agents to take an interest in the program. The county agents have assisted in selecting areas, through local farm groups, and have supported the work after its establishment in the areas.

The Director of the vocational board of education has taken an active interest in the work, and soil conservation methods are now being developed on the school farms of 116 vocational schools in Puerto Rico.

The agricultural college at Mayaguez has cooperated in training technical personnel and in establishing soil-conservation methods on the college grounds. Cooperative projects have been organized among heads of the department of engineering, the department of agronomy, and the Soil Conservation Service, whereby the students participate in the work.

The Polytechnic Institute of San German has encouraged the work, and is now offering night classes in soil conservation to its farm help and neighboring farmers.

The sugar industry has cooperated by conducting demonstrations in growing sugarcane on hillsides.

The highway departments, both Federal and insular, are cooperating and have appointed a liaison officer with the view of installing soil-conservation methods on the roadside ditches, road banks, and road fills in Puerto Rico.

The insular irrigation and water resources organizations have cooperated in supplying basic data on stream flow, silting, flood damage, and other useful data in developing a soil conservation program.

The Department of Health is cooperating by examining the health of the farmers in the soil conservation areas, and providing more sanitary facilities.

The penitentiary and insane asylum have requested the assistance of the Soil Conservation Service in developing a soil conservation program on the farms of these institutions.

The program has now been extended to the Virgin Islands, and has attracted attention in Jamaica, Haiti, Hawaii, Ecuador, Colombia, and Venezuela. This has been possible only through the vision of the chief of the Soil Conservation Service in Washington in starting the work, and the cooperative attitude and assistance given by both Federal and insular organizations in the island of Puerto Rico.

Authors' Acknowledgments

Trailing Indigo, a Promising Leguminous Forage Plant, by Robert L. Davis and Bernardo Fiol Villalobos. Page 29. To the Puerto Rico Experiment Station of the United States Department of Agriculture, which supplied land; to the Puerto Rico Reconstruction Administration, for labor and technical supervision.

Use and Limitations of Trash Barriers, by Robert L. Davis. Page 24. To the Puerto Rico Reconstruction Administration, which supplied labor, technical supervision, and land.

Tillage Tests on Puerto Rican Bench Terraces of Mucara Clay, by Robert L. Davis. Page 21. To the Puerto Rico Reconstruction Administration, which supplied labor, supplies, and technical assistance; to the Puerto Rico Experiment Station of the United States Department of Agriculture, which supplied the land and helped in the construction of terraces.

Pasture Treatment in the Ohio Valley

On the Leatherwood Creek project near Bedford, Ind., farm records secured by Marion M. Merritt and J. M. Rudy show that several farm pastures treated with 1½ and 2 tons of lime and 400 pounds of superphosphate (20 percent) per acre, produced about twice as much forage as similar pasture land that was not treated. Records were kept on 6 farms in 1938 and on 12 farms in 1939. The increased returns nearly paid for the lime and fertilizer the first year. Another application will not be needed for 3 to 5 years. Such treatment of poor pastures is justified also because it makes possible a thicker cover of vegetation to reduce soil losses and run-off, provides a more nutritious feed, and encourages farmers to keep more of their land in grass. More details of this are reported in Regional Circular 188, Dayton, Ohio, April 25, 1940.—A. T. Semple.

SOIL CONSERVATION A UNIQUE PROBLEM IN PUERTO RICO

By C. A. PRICE [1]

PUERTO RICO is an island of extremes, for within its bounds are found great variations most of which affect the agriculture either directly or indirectly. Before one can appreciate the problems that face the Soil Conservation Service in the island, he first must know something about the variations found in the type of agriculture, climate, topography, geology, and vegetation.

Puerto Rico is located at the eastern extremity of the Greater Antillean islands, commonly called the West Indies. It is approximately 1,400 miles south and east of New York City, and 1,000 miles east and south of Miami, Fla. The island itself is about 100 miles long by 40 miles wide. Recently it has been included in Region 2 of the Soil Conservation Service, with headquarters at Spartanburg, S. C.

Perhaps the most constant feature of the island is the temperature, although there is a difference of about 10° F. in the mean annual temperature between the coastal lowlands and the highest mountain districts which average approximately 78° F. and 68° F., respectively. But there are only slight seasonal and daily fluctuations in temperature; frost, or temperature above 102° F. have never been recorded. In this tropical area the northeast trade winds blow almost continually, depositing much rain on the steep mountainsides of the island, while the bordering ocean waters tend to regulate and smooth out temperature fluctuations.

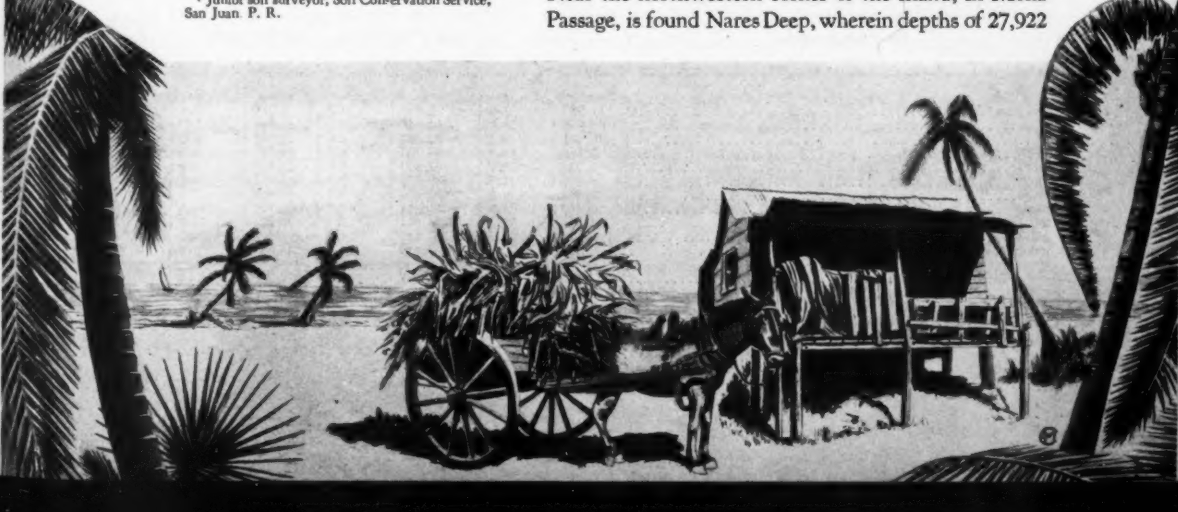
On the other hand, the climate of Puerto Rico is decidedly variable when the amount and distribution of rainfall is taken into account. The mean annual rainfall of the island will vary from 26 inches in places on the south coast to 200 inches in the northeastern mountainous region. A distance of approximately 60 miles separates these regions. In some places there is too much rainfall for the growing of certain crops, and in other places nearby irrigation must be used in order to grow almost any crop. Parts of the southwestern section of the island may be classed as semidesert, while tropical rain forests are found in other sections. The continually blowing trade winds, the high percentage of cloudless days and the tropical position of Puerto Rico make the evaporation ratio high. It has been estimated that 35 inches of rain on the north coast of the island is equivalent to about 15 inches in the northern Great Plains region of the continental United States.

The topography of Puerto Rico is extremely variable; it ranges from the flat alluvial lands on parts of the coast to the high cone-shaped mountains of the interior with their characteristic steep V-shaped valleys. The elevation range is from sea level to 4,400 feet in the high mountains of *Los Picahos* near the center of the island.

The geology of Puerto Rico is extremely complicated due to the fact that the ocean waters almost completely covered the island several times in its past geological history.

Considering the Archeozoic, Proterozoic, and Paleozoic eras as representating 85 percent of all geologic time, it is surprising to know that nearly all the rocks found in the Greater Antilles were formed during the last 12 percent of earth's history. In brief, it may be said that the central core of Cretaceous sedimentary and volcanic rocks is bordered by the Tertiary limestones and recently deposited material of the coastal sections. The island itself is supposed to represent part of the top of a mountain chain which extends deeply into the Atlantic Ocean and Caribbean Sea. Near the northwestern corner of the island, in Mona Passage, is found Nares Deep, wherein depths of 27,922

[1] Junior soil surveyor, Soil Conservation Service, San Juan, P. R.



feet are recorded. Off the southern coast, depths of from 12,000 to 16,000 feet are common. It has been said that "if the waters of the Atlantic and Caribbean could be drained, the Great Antillean islands would appear as one of the most imposing mountain elements on the earth," and that "Cerro de Punta, the highest summit in Puerto Rico, would surpass Mount Everest when viewed from the north, and would equal the highest peaks of the Andes when seen from the south."[2]

The past geologic periods have not been very kind to Puerto Rico. No coal or oil has been found on the island, and the precious metals are very limited. Only one manganese mine has enjoyed any kind of success. A large deposit of iron-bearing earth, classed as a laterite soil, has been formed; but without fuel this deposit seems destined to lie unused for many years in the future.

The vegetation of the island as seen in most places today would present a striking contrast to the natural vegetation that the early Spanish explorers found in Puerto Rico. Almost all the most important cultivated plants are exotic to the island. Plants such as sugarcane, coffee, bananas, grapefruits, and coconuts have been introduced. The virgin tropical forests have been almost entirely cut away to make room for the cultivation of crops. Farming on steep slopes for several hundreds of years has brought with it great erosional losses of the soil. Mountain streams which in the past ran clear and pure are now muddy and impure after each rainfall. Puerto Rico has well-defined natural tropical forest regions, grass regions, swamp regions, and desert regions. Under these different types of vegetation, different soils and different types of agriculture have developed. Each region calls for its special kind of soil-conservation practices.

[2] Geology of Puerto Rico. By Howard A. Meyerhoff. 1933.

The total land area of Puerto Rico, including the adjacent and dependent islands, has been given by the Insular Department of Interior as 3,400.6 square miles. The total population according to the 1935 census was 1,723,534. The average number of inhabitants per square mile in 1935 was therefore 506.8 which may be compared with 454.0 in 1930, 383.2 in 1920, 328.8 in 1910, and 280.3 in 1899 when Puerto Rico was ceded to the United States. In density of population the island may be compared to the older European countries, although these countries have many more natural resources and industries than are found in Puerto Rico.

With 506.8 people per square mile, Puerto Rico has an average of only 0.48 acre of arable land per person. Of the total 2,113,704 cuerdas[3] of land, 90.5 percent, or 1,913,047 cuerdas were in farmland in 1935. In 1910, 98.6 percent was in farmland; in 1920, 95.7; in 1930, 93.6. From 1910 to 1935 the total land in farms decreased, and the total number of farms decreased almost 10 percent. In 1910 there were 58,078 farms; in 1930, 52,965; in 1935, 52,790. The average farm in 1935 was 36.2 cuerdas in size with an average value of $81.69 per cuerda, the value of land ranging from $10 to $1,000 a cuerda. The very high-priced land is found on the coastal alluvial lands and is entirely devoted to sugarcane. Some of this land has been planted to sugarcane for 80 or more successive years, and at the present is producing more sugar per acre than ever before due to the efficient and heavy use of fertilizers, to irrigation, improved varieties, and cultural practices.

Actually, however, the average figures given above mean little unless we consider the distribution of farmland and cropland. The table shows the classification of farms by number and size based on all land in farms.

Of a total of 52,790 farms in Puerto Rico, 44,195 or 83.7 percent are less than 35 cuerdas in size, which

[3] 1 cuerda=0.97 acre.

*Table showing number and size of farms in Puerto Rico, 1935**

Size of farm in cuerdas	Farms		Area of land in farms		Area of cropland		Average size of farm	Average cropland per farm
	Number	*Percent*	*Cuerdas*	*Percent*	*Cuerdas*	*Percent*	*Cuerdas*	*Cuerdas*
Less than 3	1,782	3.4	3,305	0.2	3,057	0.4	1.9	1.7
3–5	15,223	28.8	59,448	3.1	41,442	5.0	3.9	2.7
6–9	10,103	19.1	72,372	3.8	41,523	5.0	7.2	4.1
10–14	7,387	14.0	85,170	4.5	44,013	5.3	11.5	6.0
15–19	3,779	7.2	62,600	3.3	29,602	3.6	16.6	7.8
20–34	5,921	11.2	149,909	7.8	67,012	8.1	25.3	11.3
35–49	2,468	4.7	100,430	5.2	41,966	5.1	40.7	17.0
50–99	3,137	5.9	211,324	11.0	86,511	10.5	67.4	27.6
100–199	1,731	3.3	234,621	12.3	99,274	12.0	135.5	57.4
200–499	924	1.8	270,410	14.1	117,108	14.2	292.7	126.7
500 and over	335	.6	663,458	34.7	225,842	30.9	1,980.5	763.7
Total	52,790	100.0	1,913,047	100.0	827,350	100.0	36.2	15.7

*Condensed from table No. 10, Agriculture Census of Puerto Rico, 1935.

is to say that 83.7 percent are less than the average farm size. Of the total, 49,800 or 94.3 percent are less than 100 cuerdas. Only 335 farms, or 0.6 percent of the total number, are 500 acres or more in size; but these farms total 663,458 cuerdas, as compared with the farms of less than 100 cuerdas which represent 94.3 percent of the total number and occupy 744,558 cuerdas of land. These figures show clearly one "extreme variation" in the type of agriculture in Puerto Rico. Most of the large farms are under the control of corporations and are mostly planted to sugarcane. This type of farming is found mainly on the rich alluvial coastal lands and in the interior valleys of the island. Since 90.5 percent of the land of Puerto Rico is in farms, it is not difficult to see that the small-farm type of agriculture occupies the land not devoted to sugarcane, that is, the steep-sloped mountainsides of the interior. Likewise, when it is considered that the elevation ranges from sea level to 4,000 feet or more 20 miles within the interior, it is not difficult to picture the steep slopes and the hazards of a type of farming largely devoted to tobacco, pineapples, and minor crops with the soil clean cultivated and left bare several times in a year.

Puerto Rico is fundamentally an agricultural country. Its future lies in agriculture and its development. At the present time Puerto Rico imports some $90,000,000 worth of materials from the continental United States each year, a large percentage of which may be charged to foodstuffs. The job of the Soil Conservation Service in the island is to help conserve the soil so that food production can be not only maintained for the present but increased in the future. The obstacles are numerous and severe, yet the Puerto Ricans realize more and more that their future depends to a large degree upon saving their soils.

RIO GRANDE DE LA PLATA AND SOIL CONSERVATION

By W. G. KINCANNON [1]

A CIRCUITOUS route is followed in traveling southward from San Juan, P. R., on Military Road No. 1. After 61 kilometers, or about 38 miles, you come to the town of Cayey lying in a valley in the mountains that occupy so much of the interior of the island. Cayey and the surrounding countryside is said to be about 2,000 feet above sea level. The weather is pleasant, as the evenings and nights are cool and the days generally not uncomfortably warm. The mean temperature, summer and winter, varies not more than 10°. The annual rainfall averages 55 inches and is characterized by many rainstorms of high intensities. The months of January, February, June, July, and August are rather dry and crops sometimes suffer.

Should the traveler turn left from Military Road No. 1 before reaching Cayey and shortly after leaving Las Cruces he might view a landscape dotted with little varicolored houses and small fields terraced and contour-tilled. This is the Guavate group of resettlers' farms of the Puerto Rico Reconstruction Administration. Farther along the highway from Cayey to Cidra, is the Cidra group, and then on the road to Comerio at the left of the highway and across Rio Grande de La Plata, in a landscape beautiful in its symmetry, is the Comerio group.

Starting again from Cayey and proceeding westward on Military Road No. 1, toward Aibonito, the traveler will barely have left Cayey before he is within the area of the Buena Vista group. After leaving Buena Vista he reaches the Maton group, and then with much turning and twisting along the mountain road he finally comes to the observation platform overlooking the La Plata group. La Plata is a fitting climax for a tour of the Cayey area of the P. R. R. A. Little La Plata Mountain stands like a dunce cap in the valley of Rio Grande de La Plata. Its slopes are symmetrically striped with contour strips of green crops and narrow strips of barrier plantings. The valley at the foot of La Plata and the slopes reaching upward from the Rio Grande de La Plata are similarly patterned.

The tour just outlined would take the traveler along the "front yard" of the work that has been done in the Cayey area by the Soil Conservation Service and the Puerto Rico Reconstruction Administration to control erosion and for agricultural resettlement. The work of conserving the soil on resettlers' farms in the area was started when the Soil Conservation Service established an office in Cayey in September 1937. Nineteen farms, ranging in size from 22 to 700 acres, were purchased and subdivided into small resettlers' farms, each 5 to 14 acres in size and averaging 6 acres. A system of agriculture to conserve soil and retain soil fertility and moisture was designed and its installation planned for all resettlers' farms. By December 1939

[1] In charge of soil conservation work in St. Croix, V. I. Formerly in charge of Cayey project, Soil Conservation Service, P. R.

the work of establishing the practices was approximately 90 percent complete. On completed areas it required only satisfactory maintenance on the part of the *parceleros* (resettlers).

It was not an easy matter, however, to establish conservation practices in the area. Farmers were not accustomed to contour tillage and terraces, and there was little background upon which to base recommendations of practices for farming on mountain slopes. Systematic rotations never before had been used by the small farmers.

The land purchased by the P. R. R. A. for resettlement lay almost entirely in mountainous terrain. Topographically, the whole area is characterized as a Cretaceous peneplain roughly and highly dissected, with the relatively narrow valleys bounded by precipitous slopes. The resulting hills are more or less knife-edged with gradients of from 25 to 75 percent and extremely undulating slope conditions. Extending from the bases of the hills are colluvial slopes, less severe but generally rolling in nature. The flow lines of intermittent streams leading to the Rio Grande de La Plata have gradients often ranging from 10 to 25 percent. The soils over the entire area are predominantly clays and silty clays of varying depths above the rocky parent material.

For purposes of standardization of method and of training personnel for conservation work, a generalized scheme of conservation operations was devised gradually. In the development of the procedure, and by ts application, the establishment of demonstrations and trials was accomplished. The scheme was necessarily tentative and it may therefore be changed from time to time; but nevertheless it lends itself to the generally recommended plan of land-use capabilities.

After a study of conditions of soil and slope along with some of the engineering and agronomic limitations so imposed, eight groupings were made, each of which embodied pertinent physical factors and recommended applications. This grouping is outlined below. The numerical arrangement of groups is designed to point out the conditions most difficult to cope with as they range into the more favorable situations. Somewhere in the Cayey area each group recommendation has been put into practice.

Group 1.—The Mucara, Los Guineos, Cialitos, and Naranjito soils are included in this group when situated on slopes greater than 30 percent if erosion has been so severe as to remove more than 75 percent of the topsoil. Also included in the group are all soils situated on slopes greater than 75 percent, irrepective of the degree of erosion. The soils falling in the group are described as derivatives of Cretaceous volcanic pyroclastic rocks, with andesitic tuff, minor ash, and shale origin. The depth of the Mucara soil ranges from 2 to 10 inches, and the depth of the others from 2 to 10 feet.

Crop cultivation is not considered practical for such conditions. Instead, development into pasture or forest is recommended, with contour furrowing on 2-foot vertical spacings for moisture conservation. Each furrow should be blocked at 10-foot intervals in the manner of basin listing. In the cultivation of forest trees it is recommended that the surface of the soil be disturbed only for short distances about each tree in crown cultivation.

Group 2.—This group comprises the Mucara and Naranjito soils on slopes ranging from 45 to 75 percent, with slight to moderate erosion or with 25 to 75 percent of the topsoil eroded away. The soil is usually from 4 to 8 inches in depth.

It is conceded without question that the better practice would be retirement of such terrain to pasture or forest. It must be remembered, however, that the density of population in Puerto Rico and the accompanying seriousness of the economic condition of *el jibaro* (the country man) make thorough utilization of the land necessary. For this reason a 2-year or longer crop rotation is established on land falling within this group. Tobacco, sweet potatoes, beans, vegetables, and grasses are recommended in conjunction with the regular planting of leguminous green-manure crops. Mechanical handling of surplus water is not considered wise; instead, contour tillage is induced by the windrowing of field trash and crop residue along lines laid on a grade not exceeding an 0.8-foot fall for 100 feet. The vertical interval of such barriers, or buffer strips, is not greater than 6 feet—this because subsequent plowing of the interval, and soil flow, cause deposition at the barriers and eventually the formation of bench terraces. As the bench forms, stiff-stemmed grasses may or may not be planted in the barrier further to induce deposition, and stoloniferous grasses may be planted on the gradually forming bank below the barrier to strengthen the bench.

Group 3.—Catalina soil is a Cretaceous soil originating from andesitic tuffs, ash, and shale, and has a solum depth of 10 to 15 feet. Its occurrence, along with that of Cialitos and Los Guineos soils, on slopes from 45 to 75 percent where erosion has removed over 75 percent of the original topsoil comprises the third group.

Hillside ditches and contour cultivation make an interesting pattern on this La Plata farm near Cayey. Conservation practices are in evidence on Little La Plata Hill in the right foreground.

Treatment for conditions of this group are identical with those for Group 2, except that the greater depth of the topsoil of the soils here found allow the growth of a wider variety of crops. To the crops and rotations of Group 2 are added Irish potatoes, rice, and the tropical crops, yams, yautias, plantains, and bananas.

Group 4.—The soils, degrees of erosion, and crops of Group 4 are the same as for Group 2, the difference being that in this group the slopes range from 15 to 45 percent. Recommended practices therefore differ, not in agronomic, but in engineering features.

Eventual bench-terrace formation is again foreseen but through a different method of handling surplus surface water. The necessity of regular interception and confined disposal was deemed necessary; hence small ditches, or diversions, on grades not in excess of 1 percent, are dug around the slopes on vertical spacings of not more than 6 feet. Field trash and crop residues are deposited parallel to the ditches on their uphill bank, thus allowing bench formation from that point and still maintaining water interception at the foot of the gradually forming bench. When the bench has formed to a height whereby it is no longer safe or practical to utilize the original diversion ditch for interception, it is erased and a new small ditch is established just above the barrier. As the bench further forms, the necessity of the ditch is removed by the establishment of a bench terrace, not flat, but having a channel for water diversion at the foot of the bench above. Thus a channel is again placed in the original lateral position of the ditch but on a lower level, and the bench terrace becomes also a channel-type terrace.

Group 5.—In this group are included the deeper phases of Cialitos, Los Guineos, Catalina, and Naranjito soils on slopes from 15 to 45 percent where erosion has removed from 25 to 75 percent of the topsoil.

The agronomic practices of Group 3 are again recommended here. Water interception and bench formation are secured by the construction of furrows on grades no greater than 1 percent and spaced vertically not over 6 feet. Cane-like grasses, such as Merker and elephant grasses, are planted on the downhill bank of the furrow. As the bench forms by soil manipulation and flow against the plant barrier, the furrow channel moves toward the bench above until it eventually is established at the foot of the bench.

Group 6.—Cialitos, Catalina, and Los Guineos soils of Group 5, on slopes of 15 to 40 percent only, are included in this group. Agronomic practices are the same as previously recommended, the difference being only in the method of mechanical manipulation.

Where justified economically, the bench terraces are constructed outright, with diversion of water handled by channeling the bench with a 1-percent slope of bench surface toward the toe of the terrace above. Grade along the bench should not exceed 0.8 percent and vertical spacing 6 feet. Bank slope of the bench should be as near the natural angle of repose of the soil as practicable (1:1 slope, approximately) with stoloniferous grasses for added safety and protection.

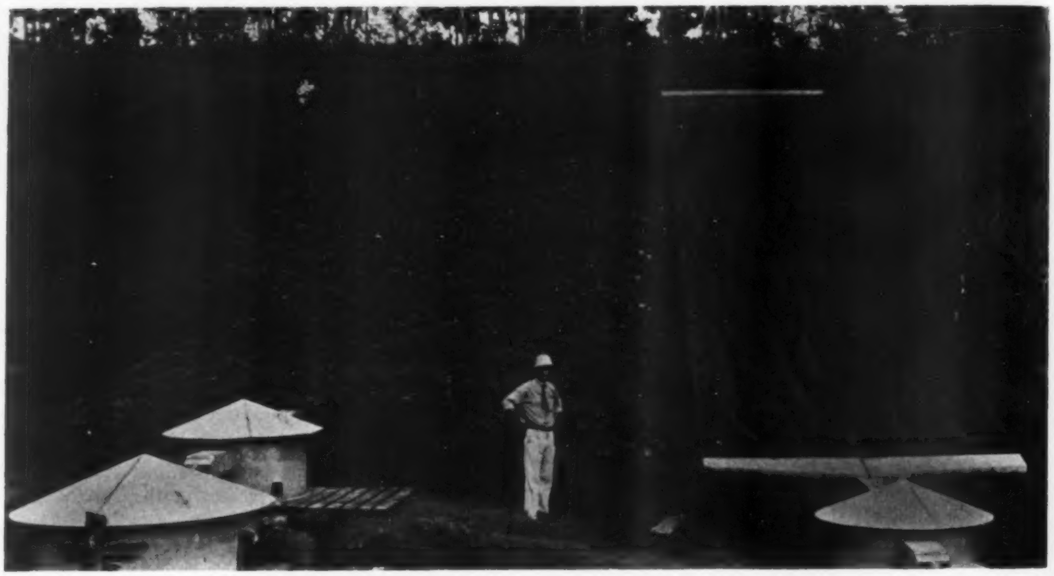
Group 7.—Catalina, Mucara, Cialitos, Moli, Toa, and Estacion soils on slopes less than 15 percent comprise this group. The latter three soils include erosive deposition (colluvial) and rock weathering of slightly different geological history than the other soils.

Agronomic practices remain unchanged for this group, being the same as for Group 3. Instead of bench terracing by any means, a modified ridge or

(*Continued on p. 20*)

HOW EROSIVE EFFECTS OF INTENSIVE RAINS ON STEEP SLOPES MAY BE DECREASED

By JOEL W. ELLIOTT [1]



Left to right: sour paspalum, sweet potatoes, fallow, guinea grass.

CATALINA clay slopes of 35 to 45 percent have been considered representative of large areas requiring erosion protection in Puerto Rico. In view of this, run-off plots with catchment tanks were located on such clay slopes near Mayaguez and put into operation on June 1, 1938.[2]

The history of this land for the past 40 years is somewhat as follows: For 20 years it was overgrazed pasture; then followed 10 years of use in clean cultivation around experimental plants; during the last 10 years the land lay in unproductive abandonment. Erosion was moderate to severe. Much of the topsoil from these slopes had been lost through the uses to which the soil was subjected in combination with the average rainfall of 81.7 inches a year. In spite of the rainfall, water conservation is an important feature, as precipitation is concentrated in about 8 months of the year.

The land was cleared, plowed, leveled, and planted with cover crops in alternate horizontal strips.[3] Six months later the field was replowed and harrowed and the plots were leveled horizontally and planted in small contour sections. In this way the slopes and soil profiles were disturbed as little as possible and care was taken to guard against excessive erosion during the preparation period. An 8–14–14 fertilizer was applied at the time of all plantings.

Nine pairs of duplicate plots, one-seventieth acre each, were thus located on slopes of 35 to 42 percent and put in operation on June 1, 1938. All vegetative covers were well established by this time as planting had been done 6 months previously. Later, certain of the species failed and were replaced by cultivated crops. All plots have horizontal lengths of 51.86 feet and widths of 12 feet. Sheet-metal border plates completely surround each plot on the two sides and upper end. On the lower end the plate is driven flush with the ground so that all run-off flows on to a covered sheet-metal apron and is led through a flume into a round sheet-metal settling tank. Overflow from this passes through a "Geib Multislot Divisor" which allows one-seventh or one-ninth to go into a second sheet-metal tank. All tanks, flumes, and divisors have sheet-metal covers to prevent entrance of rain. After each rain the mixture of run-off and soil in the tanks is

[1] Assistant soil technologist, Soil Conservation Service, Mayaguez, P. R.

[2] All field equipment was designed and installed by V. W. Thalman, associate agricultural engineer, Soil Conservation Service, and A. Roura, principal engineering aide, Puerto Rico Reconstruction Administration.

[3] Agronomical planning and supervision were rendered by R. L. Davis, agronomist, Soil Conservation Service, Mayaguez, P. R.

TABLE 1.—*Summary of rainfall data from May 1, 1938, to Dec. 31, 1939 (U. S. Department of Agriculture, Soil Conservation Service Research Station, Mayaguez, P. R.)*

Months	Stormy days having run-off	Total rainfall			Average duration of—		Intensities in inches per hour for rains causing run-off			
		39-year average	1938–39 actual	Causing run-off	Storm causing run-off	Falling rain causing run-off	Maximum for—		Average for period of—	
							5 min.	30 min.	Storm	Falling rain
1938	*Number*	*Inches*	*Inches*	*Inches*	*Hrs. Min.*	*Hrs. Min.*	*Inches*	*Inches*	*Inches*	*Inches*
May	11	8.27	9.69	8.69	3 18	2 53	3.00	1.50	0.26	0.30
June	7	8.97	7.38	6.06	4 29	2 48	4.50	1.70	0.19	0.31
July	13	10.73	11.92	11.08	3 04	1 28	4.50	3.25	0.28	0.58
August	9	11.37	6.11	5.71	2 43	1 20	5.00	2.00	0.23	0.47
September	16	10.89	11.95	11.71	2 50	1 05	3.50	2.60	0.26	0.67
October	7	9.79	4.63	3.70	56	37	3.00	1.45	0.57	0.84
November	10	5.95	5.58	4.91	1 21	38	4.20	1.86	0.36	0.78
December	5	2.60	4.70	4.48	49	49	3.80	2.60	0.11	0.11
1939										
January	1	2.00	0.86	0.52	1 20	1 20	1.20	0.64	0.39	0.39
February	1	2.18	1.43	0.90	1 40	1 00	2.28	0.78	0.54	0.90
March	6	3.78	7.28	6.40	3 55	1 35	3.84	1.84	0.27	0.77
April	8	5.17	4.86	3.81	2 39	51	3.12	1.40	0.18	0.56
May	13	8.27	9.91	8.69	2 00	1 30	5.52	2.92	0.33	0.44
June	5	8.97	5.63	4.90	2 43	1 44	3.12	1.30	0.36	0.56
July	12	10.73	13.28	12.43	2 18	1 37	5.24	2.06	0.45	0.60
August	15	11.37	14.11	13.84	2 46	1 03	4.32	2.92	0.33	0.87
September	8	10.89	6.00	4.53	2 14	1 35	3.36	1.76	0.29	0.41
October	9	9.79	7.34	5.89	1 23	1 08	3.12	2.32	0.47	0.58
November	6	5.95	3.42	2.72	2 35	2 35	1.92	0.76	0.17	0.17
December	3	2.60	1.67	1.36	3 46	3 00	1.56	0.64	0.12	0.15

allowed to settle. Top liquid and sludge (underlying mud and water) are separately drawn off and each is weighed and sampled in increments. Proportionate sampling builds composite samples of each. The percentage of oven-dry soil and water in the samples are determined in duplicate. From these percentages and the total weights of top liquid and sludge, the actual amount of dry soil and of run-off water from each storm is determined.

Rainfall and rainfall intensities are ascertained for each storm by standard and recording rain gages. The prevailing rains at Mayaguez are of the convectional current type. Clouds will cover the sky over a limited area, then let go, and hurl their water upon the slopes below. Two or three such rains falling during 1½ hours may comprise a storm period lasting from 1½ to 2½ hours in an afternoon (see table 1).

Rates of downpour or intensities, measured in inches per hour, such as 4.3, 5.2, and 5.5 inches during 5 minutes or 2.32, 2.60, and even 2.92 inches per hour during 30 minutes, are reached by these rains. For the entire period of falling rain the average intensities are 0.6, 0.7, 0.8, and 0.9 inch an hour.

Storms causing run-off average between 9 and 10 a month for 8 months, from April to November, inclusive. From December through March the average is only 3 such storms.

The high intensities of these rains influence greatly the amounts of run-off from areas devoid of or almost without vegetation. The coefficient of correlation between the average rates of water run-off from two nonvegetated desurfaced plots and average intensities of falling rain from 60 storms is 0.81 ± 0.044. Thus 65.59 percent of the variance existing between rates of run-off may be explained by differences in average intensities of rainfall when no differences exist in degrees of slope, vegetation, or soils. Therefore, in considering erosion protection for any given area in Puerto Rico, it is obvious that we must consider means of guarding against these high intensities or the force of these rains.

Where this protection is not supplied as on nonvegetated areas, erosion may be so severe as to cause a loss of 1.95 or 2.54 inches of surface soil in 19 months. This applies to the fallow and the desurfaced duplicate plots. The losses are equivalent to 2.194 and 3.009 tons of soil eroded per acre per each inch of rain causing run-off. Water run-off from the same plots amounted to 31.8 and 38.1 percent of the rainfall. Differences between the two sets of duplicates might be attributed to the presence of organic matter in the topsoil of the fallow plots and its scarcity in the surface of the desurfaced plots, and to an average slope difference of 6.7 percent in favor of the desurfaced plot. The average slope of the fallow plots is 40.08 percent while that of the desurfaced plots is 46.80 percent. See table 2.

Squash plots lost as run-off 26.98 percent of their rainwater and 0.705 ton of soil eroded per acre per inch of rain. This suggests a canopy effect of the leaves acting as a buffer against the falling rain with little protection afforded against the flowing water.

TABLE 2.—*Relation of plant cover to the control of erosion and run-off averages. Data from 1/70-acre duplicate plots on Catalina soil having slopes of 35 to 42 percent. (U. S. Department of Agriculture, Soil Conservation Service, Research Station, Mayaguez, P. R.)*

Surface treatment	Period data were obtained	Rain causing run-off	Soil eroded			Water run-off		
			Per acre	From surface	Per acre per inch of rain	Per acre	Depth	Loss of rainfall
		Inches	*Pounds*	*Inches*	*Tons*	*Cubic feet*	*Inches*	*Percent*
Desurfaced [1]	June 1, 1938–Dec. 31, 1939	113.64	683,901	2.541	3.009	157,197	43.269	38.08
Fallow [2]	June 1, 1938–Dec. 31, 1939	113.64	498,693	1.950	2.194	131,370	36.160	31.82
Sugarcane (holes) [3]	Oct. 23, 1938–Dec. 31, 1939	75.12	38,432	0.153	0.258	27,534	7.379	10.09
Sugarcane (furrows) [4]	Aug. 20, 1938–Dec. 31, 1939	93.52	3,275	0.013	0.018	14,737	4.057	4.34
Sweet potatoes [5]	June 1, 1938–Dec. 7, 1938	44.94	6,463	0.024	0.072	5,106	1.405	3.13
Jackbeans and field beans [6]	Dec. 8, 1938–Aug. 1, 1939	40.36	21,926	0.084	0.272	11,541	3.177	7.87
Squash [7]	Aug. 1, 1939–Dec. 31, 1939	28.34	39,951	0.152	0.705	27,775	7.645	26.98
Molasses grass [8]	June 1, 1938–Dec. 31, 1939	112.28	2,057	0.008	0.009	43,369	11.938	10.63
Bermuda grass	June 1, 1938–Dec. 31, 1939	113.64	1,648	0.007	0.007	36,255	9.979	8.78
Guinea grass	June 1, 1938–Dec. 31, 1939	113.64	2,787	0.011	0.012	50,448	13.886	12.22
Sour paspalum grass	June 1, 1938–Dec. 31, 1939	112.28	433	0.002	0.002	14,556	4.007	3.57
Green cohitre [9]	June 1, 1938–Oct. 21, 1938	37.26	299	0.001	0.004	2,729	0.751	2.02

[1] The surface 2 feet of soil removed with the exposed soil kept bare of vegetation.
[2] Surface soil kept bare of vegetation and not cultivated.
[3] Sugarcane planted Oct. 22, 1938, by cuttings at each corner of 4-inch deep, 2-by-2-foot holes which are in parallel columns and lines 2 feet apart each way.
[4] Sugarcane planted Aug. 20, 1938, by cuttings planted 8 inches apart in contour furrows which were 3.5 feet between centers and 8 inches deep.
[5] Sweet potato slips planted May 2, 1938, and followed by jackbeans Dec. 8, 1938.
[6] Jackbeans planted Dec. 8, 1938, and cut June 6, 1939. Field beans had been planted in them May 11.
[7] Squash were planted Aug. 1 and replanted Aug. 7, 1939, following the field bean harvesting on Aug. 1, 1939.
[8] Poor stand on one molasses grass duplicate until October 1938.
[9] Green cohitre planted Sept. 16, 1937, followed by sugarcane in holes October 1938.

Sweet potatoes planted May 2 and harvested December 7, 1938, permitted only 3.13 percent of their rain to run off, with an erosion of 0.072 ton of soil per acre per inch of rainfall. In contrast, and following these on the same plots, jackbeans and field beans between December 8, 1938, and August 1, 1939, lost as run-off 7.87 percent of their rainfall and 0.272 ton of soil eroded per acre per inch of rain.

Water run-offs from Guinea and molasses grasses, as judged by percent of rainfall, were greater than from any of the cultivated crops such as cane, beans, or sweet potatoes. Water run-offs and soil lost from sour paspalum grass and green cohitre were negligible.

Sugarcane when planted in holes, an old method of hillculture, permitted during 14 months an average of 10.09 percent of the rain to run off and 0.258 ton of soil to be eroded per acre per inch of rain. Only 4.34 percent of rainfall and 0.018 ton of soil an acre per inch of rain were lost during 16 months by cane planted in furrows following the contour of the land. This is a saving by the contour furrows of 0.24 ton per acre per inch of rain, or 15.84 tons an acre, for the 66 inches of rain causing run-off in 1939. Thus the cane in contour furrows retained 0.11 inch of soil more than the cane in holes. As 4 inches represents the average depth of topsoil in the hills for similar slopes, this saving is significant.

Sugarcane in contour furrows was planted August 20, 1938, by cuttings at an angle of 37° and 8 inches apart. The furrows were 3.5 feet apart between centers and 6 inches deep. That in holes was planted October 22, 1938, by cuttings, at each corner of 2-by-2-foot holes that were 4 inches deep and arranged in parallel columns and lines 2 feet apart each way.

The average slope of the plots having holes is 45.6 percent while that of the contour furrows is 42.3 percent. By August 1, 1939, the total calculated water-holding capacity for all the holes in a 1/70-acre plot was only 0.4 cubic feet, while that of all contour furrows was 7.5 cubic feet. The average saturation requirement for the first 12 inches of soil on the contour-furrowed plots was found to be 0.52 inch in November 1938, while that of the plots with holes was 0.48 inch.

The surface area shaded by the foliage at noon on August 1, 1939, was 56 percent for the holed and 85 percent for the contour-furrowed plots. Shaded areas may be considered as a guide to the rainfall interception formed by the foliage. Bare ground exposed on the former was 83 percent of the total surface, while only 50 percent of the contour-furrowed plots was exposed to washing. The contour-furrowed plots retained 5.75 percent more of the rainfall than did the holed plots. This was equivalent to an average difference of 16 cubic feet a month for 14 months in favor of the contour furrows.

On January 16, 1939, 26,600 marketable stalks per acre were estimated to be on the plots with holes, with 24,500 per acre on the contour-furrowed plots. The former canes averaged 70.26 inches in length and 1 3/32 inches in diameter. The average stalk from the contour furrows was 85.82 inches long and 1 5/32 inches in diameter. Seed cane and tops are not included in these measurements. The yield per acre of the contour furrows was 57.69 tons while that from the holes was 29.51 tons. The cane in contour furrows thus produced 95.49 percent more than the cane in holes.

PASTURES IN PUERTO RICO

By H. W. ALBERTS [1]

DURING the century just past there has been a profound change in the percentage of land utilized for pasture in Puerto Rico. As late as 1828 only 3 percent of the total area of land was under cultivation, with 24 percent in pasture and the remainder still in forest, brush, and swamp land. At the close of the century the cultivated area was increased to 12 percent and the pasture area to more than 50 percent. For several decades during this period there was a considerable export trade in livestock, hides, and tallow. Some of the best productive areas were in pasture. In 1905 the area in pasture was 57 percent. With the development of sugarcane, tobacco, citrus, and pineapple culture, great inroads were made on the pasture lands; they were pushed to the poorer and more rugged areas formerly occupied by forests. Export in animals and animal products ceased entirely.

The changes in land use are shown in the table. Data were obtained from the United States Department of Agriculture, Department Bulletin No. 354, "Forests of Porto Rico," by Louis S. Murphy, and from the United States Census of 1935.

Table showing land use in Puerto Rico in four periods

Land use	Percent of total area			
	1828	1900	1912	1935
	Percent	*Percent*	*Percent*	*Percent*
Cultivation	3	12	23	39
Pasture	24	52	47	36
Timber, brush, swamp, public, and other use	73	36	30	25

During the past quarter of a century the area of cultivated land was doubled again; it encroached upon the pasture land and reduced it to the extent of about 35 percent of its peak acreage.

Nearly all the land of the island is potential pasture land. Palatable native grasses thrive wherever the forests have been removed. Owing to the density of population, nearly all the land has been planted to crops at one time or another, even the steep hillsides where the soil is shallow and subject to severe erosion. Most of the hillside lands formerly were subjected to primitive agricultural practices. The forest trees were felled and set on fire. Sometimes the larger ones were killed by girdling and left standing. Beans, bananas, corn, rice, yautias, and other crops were planted on the burnt-over areas where the ashes had enriched and sweetened the soil. Little cultivation was given these crops and the cropping seldom continued for more than 3 years. Eventually, as the fertility of the soil decreased and the surface soil was lost by erosion, and as grasses and other volunteer vegetation got the upper hand, the area was abandoned and a new clearing was made. This practice is quite rare now, as the population is so dense that it is necessary to raise crops on all available land.

In some hilly areas where commercial crops, such as tobacco, sugarcane, pineapples, cotton, and corn are produced on a larger scale, and where crops are produced primarily for household use, the land is left idle for a considerable length of time during the intercropping period. Such fields are soon covered with volunteer vegetation consisting mainly of grasses. If the farmers keep livestock the area is utilized for temporary pasture during this period.

Near the larger centers of population where numerous dairy herds are kept by farmers, the cows are provided with pasturage supplemented by green feed. The size of the pastures and the quality of feed in the pasture vary considerably. The area used for pasture by some dairy farmers is so small that it is only an exercising lot, while other farmers have large areas of meadow lands of native grasses or lands that have been planted for pasture purposes to guinea grass. Some farmers rotate their pasture lands with sugarcane and other crops.

On the south side of the island where cattle for work oxen are bred and raised, and on the north side of the island in the sandy coastal region near Arecibo where dairy animals are kept, the pasturage consists mainly of planted guinea grass.

The work animals are pastured until the beginning of the harvest of sugarcane. During the entire harvest period they are fed on cane leaves. After the close of the harvest season they are pastured again, and when feed in the lowlands is scanty some are taken to woodland pastures higher up in the mountains.

Woodland pastures usually are found on lands too poor or too steep for cultivation. The number of trees on such areas is decidedly variable and ranges from a

[1] Agronomist, Soil Conservation Service, Rio Piedras, P. R.

few to many trees per acre. Areas that are too densely forested yield little pasturage.

Although wet lowland areas usually are covered with a dense growth of grass they are not pastured during the wet season because of the presence of foot and intestinal parasites. During the dry season, when the surface soil is firm and not saturated with water, such areas can be pastured.

The carrying capacity of good pastures is approximately one cow on 3 acres. Little care is given old pasture lands except that when unpalatable plants which have invaded the areas become too numerous they are cut with a machete. Some of the most common weedy plants that infest pastures are morivivi (*Mimosa pudica*), Santa Maria (*Vernonia albicaulis*), hedionda (*Ditremexa occidentalis*) and aroma (*Acacia farnesiana*).

Native Pasture Grasses

The species of grasses that are found in native pastures vary mainly with the soil moisture. Other factors that affect their distribution are soil types, soil fertility, and tillage.

Wet lowland grasses.—On wet lowlands subject to frequent periodic floods and where the ground is wet almost throughout the year, ricegrass (*Leersia hexándra*) thrives well. Areas that are occupied by this species of grass can be pastured during the short dry season. Para grass (*Panicum purpuráscens*) and Caribgrass (*Eriochloa polystachya*) thrive in similar although somewhat drier situations. Their herbage is succulent and palatable. Both species are cut extensively for feeding in the green state.

Moist lowland grasses.—Moist lowland that is less subject to floods is usually occupied by carpet grass (*Axonopus compressus*) and mission grass (*Paspalum conjugatum*). Some farmers have large fields, resembling meadows, comprised of these grasses. Dairy cattle for city milk production usually are pastured on such lands.

Moist upland grasses.—Old, moist and well-drained upland pastures have St. Augustine grass (*Stenotaphrum secundatum*) as the dominating species. If the pastures have been established only recently they usually have a mixture of smut grass (*Sporobolus indicus*), *Paspalum conjugatum* and Bahia grass (*Paspalum notatum*) on the ridges, and carpet grass (*Axonopus compressus*) in the valleys and depressions.

Dry upland grasses.—The most common grass found in dryland areas is *Sporobolus indicus*. This species is tolerant to a wide range of conditions and is more widely distributed over the island than any other. Among the other dry-land species of grasses are Bermuda grass (*Cynodon dactylon*), grama (*Bouteloua heterostega*), buffel grass (*Pennisetum ciliare*), *Chloris inflata*, sourgrass (*Trichachne insularis*) and *Andropogon virgatus*.

Bermuda grass (*Cynodon dactylon*) is found as a weed in cultivated crop lands throughout the island. It is used to a limited extent as a pasture grass on the northern sandy coastal plain west of Arecibo. *Bouteloua heterostega* is found in dry upland areas on the south side of the island. It is drought resistant and goes into a dormant state during the dry season. It is said to be less palatable than *Sporobolus indicus*.

Pennisetum ciliare is found in the dry lowland region from Salinas to Ponce. It is resistant to drought and constitutes the main native pasture grass of this part of the island. *Chloris inflata* is used for pasture on dry lowlands on the south side of the island. It requires more moisture for its development than *Bouteloua heterostega*. Sourgrass (*Trichachne insularis*) is low in palatability. Cattle will not eat it as long as other species are available. During the latter part of the droughty period, cattle graze it in the eastern part of the island. *Andropogon virgatus* is grazed as a pasture grass on the southern hilly areas of the island when no other pasture forage is available. The grass is low in palatability and is not grazed while it is green. During periods of extreme drought the cattle will feed on it to keep from starving.

Volunteer grasses on lands during the intercropping period.—These grasses consist mainly of annuals that appear soon after completion of intertillage of such crops as sweet potatoes, beans, corn, and yautias. Although the forage that is produced is not abundant, utilization of these grasses as temporary pastures is common.

Pasture Supplements

Supplementary pasture grasses consist of two classes: (1) Those that are planted to be cut for green feed and, (2) those that grow wild and are cut wherever they may happen to be found. The first class of grasses must compete with tilled crops, while the second class is obtained from idle lands or along roadsides. The first class may be subdivided into two groups as follows: (a) Those species that are planted solely for the purpose of cutting and feeding and, (b) those which may be planted for cutting and feeding green and which may also be used for pasturage. Other pasture supplements consist mainly of sugarcane tops and leaves, silage, and concentrates imported from the States.

Grasses planted only for cutting and feeding green.—Three kinds are used for this purpose—Merker grass, elephant grass, and Guatemala grass. All these require a fertile soil with abundant rainfall for their optimal development. They can be cut from 4 to 6 times a year depending on the stage of maturity at which they are fed. They cannot withstand continuous grazing or trampling.

Merker grass and elephant grass are varieties of the same species, *Pennisetum purpureum*. In general, farmers in the eastern part of the island prefer Merker grass while those in the western part of the island prefer elephant grass. There is a slight difference between the two in field performance: Merker grass matures earlier, is shorter than elephant grass under similar soil conditions, has more white bloom on the culms, becomes fibrous sooner, has thinner stems and if cut at the optimal feeding stages it may be cut oftener than elephant grass. Merker grass is also more resistant to Helminthosporium disease. Elephant grass is more widely distributed throughout the island than Merker. The cultural practices are the same for both varieties. The land is plowed and left fallow for about 2 weeks. It is then replowed and harrowed. Parallel trenches about 2½ feet apart and 4 to 6 inches deep are then made across the field. The cuttings are then laid on one side of the trench so that when the trench is again filled with soil one node is above the ground and at least two nodes are beneath the surface. The field should be weeded once after planting. No further cultivation is necessary. After a period of 3 months the first cutting can be made. Subsequent cuttings will produce higher yields because the plants stool profusely.

Guatemala grass (*Tripsacum laxum*) is propagated by planting cuttings or clump divisions. I have not found viable seed in Puerto Rico. The inflorescence is formed during the month of December. At the time when the stigmas have emerged and the ovaries are receptive the stamens are aborted and do not produce viable pollen. Although cuttings may be used in establishing a stand, better success is obtained by planting clump divisions.

Grasses planted for feeding green and for pasture.—The two species in this group are guinea grass (*Panicum maximum*) and malojillo, the Puerto Rican common name for Para grass (*P. purpurascens*). The cultural practices for guinea grass is similar to that of Guatemala grass, except that in guinea-grass plantings the weeds are removed from among the plants until they reach the blossoming period.

The cultural practices for malojillo are similar to those for Merker and elephant grass, except that longer culms are used and the planting must be done when the soil is moist. Malojillo has a hollow stem and is more subject to injury by desiccation.

Grasses not planted but cut and fed green.—The most desirable species are malojillo and guinea grass that may happen to grow in ungrazed abandoned fields or along roadsides. If these species are not available goosegrass (*Eleusine indica*), *Paspalum plicatulum* or other palatable species are used.

Sugarcane tops.—During the sugarcane harvesting season, on the southern side of the island, cattle are fed almost entirely on the sugarcane tops. Pastures are short during this time due to the small amount of rainfall.

Establishment of Pastures

Two methods are used in establishing pastures: (1) Cultivated fields are abandoned and allowed to grow up to volunteer vegetation, or (2) the land is prepared by plowing and harrowing, and is then seeded or planted with the definite intention of establishing a pasture.

Tilled lands that are abandoned are soon covered with vegetation, most of which consists of various species of annual grasses. There are several stages of succession of species, with one stage gradually merging into the next. For example, on the north side of the island the first stage occurs during the last months of the cropping period, before the crop is harvested. It is characterized by the appearance of short-lived annuals consisting mainly of red sprangletop (*Leptochloa filiformis*), jungle-rice (*Echinochloa colonum*), and everlasting grass (*Eriochloa punctata*). After the crop has been harvested the second stage appears; its main species are the crabgrass (*Digitaria horizontalis*), goosegrass (*Eleusine indica*) and sometimes knotroot bristlegrass (*Setaria geniculata*). The third stage appears about 2 or 3 months after harvesting and is characterized by the presence of *Paspalum conjugatum*, carpet grass (*Axonopus compressus*) and zacaton (*Andropogon bicornis*). The fourth stage, which appears several years after abandonment, is characterized by the dominance of *Sporobolus indicus*, St. Augustine grass (*Stenotaphrum secundatum*) and Bahia grass (*Paspalum notatum*). Grazing plays an important part in the succession; development of the palatable species is retarded while that of the less palatable ones is enhanced.

In some sections on the south side of the island the first stage of succession consists of redtop millet (*Panicum adspersum*). The intermediate stages con-

sist mainly of gazon (*Paspalum fimbriatum*), crowfoot grass (*Dactyloctenium aegyptium*), and *Sporobolus indicus*. The final stage, as found in old pastures, consists of *Sporobolus indicus*, *Andropogon virgatus* and *Bouteloua heterostega*, with the last-named species dominating.

Some pastures are established by sowing the seed of grasses. Owing to the continuous vegetative growth of tropical pasture grasses, the seeds must be collected by hand, at a time when the largest proportion in the inflorescence is mature. Many seeds are therefore immature, and the germination is comparatively low. The seeds of only a few species are utilized, among them molasses grass (*Melinis minutiflora*), and guinea grass (*Panicum maximum*).

The seedbed for molasses grass can be prepared at any time of the year but the best time is during the dry season, provided the soil is not too hard for plowing or too lumpy to make a fine smooth seedbed. Preparing the land during the dry season reduces the weed growth. Soon after the seedbed has been prepared the seeds are sown on top of the ground. The first rains will cover them to a sufficient depth. After 4 months from seeding the area is ready for pasturage. Owing to the peculiar molasses odor of the grass, cattle do not relish it at first, but after they are accustomed to it they thrive on it. Molasses grass tolerates poor soil, seasonal drought, and trampling by livestock. It is usually grown on poor hilly lands.

Guinea grass is the most valuable pasture grass in the dry sections of the island. It requires a more fertile soil than molasses grass. The land is plowed and left fallow for some time. The first plowing loosens the soil and subdues the vegetation although not completely. After about 2 weeks it is plowed a second time and then harrowed. Although it can be established by planting the seed, greater success is obtained by planting clump divisions of parent plants. These are set in rows about 2½ feet apart, and 2½ feet apart in the row. The space among the plants is cultivated or hoed until the inflorescence has formed. The field is then laid by, and the interspaces are seeded by self-sowing of shattered seeds from the established plants. Good stands are obtained also by sowing the seeds in corn after the last cultivation. After a period of about 3 months from the time of planting, the area is ready for pasture. Guinea grass thrives well on rich soils. It is resistant to drought and therefore forms the principle pasture grass on the south side of the islands.

Malojillo requires a more moist soil than guinea grass and therefore is more commonly planted for pasture on the north side of the island where rainfall is more abundant. It is never propagated by planting the seed. The seedbed is prepared by double plowing; that is, a first plowing is made which is followed in about 2 weeks by a second plowing. Long parallel trenches about 4 to 6 inches deep and 2½ feet apart are made across the field. Planting is done when the soil is moist. Stolons of about 4 feet in length are laid in the trenches so that the tips will be on the ridges and the remainder in the trenches. The part in the trenches is then covered with soil. Owing to its stolon-forming habit this grass soon covers the area. After the area is completely covered, stolon formation ceases and only erect culms are produced. The area is usually ready for pasture about 3 months from the time of planting.

Relation of Pastures to Soil Conservation

On well-managed pasture lands, soil formation and soil erosion approximately balance each other. Nearly all the surface soils on the island from a depth of a few inches to several feet, are extremely porous and have a high absorptive capacity for moisture. Below the surface layer the interspaces of the soil are filled with fine particles that are packed so firmly that they form an impervious layer similar to hardpan. Comparatively little water percolates through this layer; instead it gradually travels along the surface of this impervious layer below the porous topsoil to lower levels.

Although much rain falls in frequent intermittent showers, the period of duration of the showers usually is not longer than 10 or 15 minutes. The rainfall of most showers is absorbed almost completely by the spongy layer of surface soil, and consequently there is little or practically no surface run-off. When heavy showers of longer duration occur, the porous surface layer becomes supersaturated and the additional water runs off on the surface to lower levels, to form numerous deep finger gullies on tilled lands. Furthermore, owing to its great velocity as it runs down the slope, it carries large quantities of soil in suspension. It is estimated that 69 percent of the tilled land on the slopes of the island have lost more than 25 percent of their surface soils through erosion.

Pasture lands suffer comparatively little from soil erosion. Although less water is absorbed by the soil immediately following each shower because of the compactness of the surface layer that has not been loosened through tillage, there is comparatively little erosion after the soil has reached its point of satura-

(*Continued on p. 23*)

Sodding an outlet channel by hand. The man at the right is punching a hole where the clod of protecting grass is to be placed.

VEGETATIVE PROTECTION OF TERRACE OUTLET CHANNELS

By W. LÓPEZ DOMÍNGUEZ [1]

OUTLET CHANNELS in Puerto Rico should be protected with some form of vegetation, preferably a dense low-growing grass, to prevent them from eroding. The grasses to be used and also the planting methods vary in different localities according to precipitation, soil type, and slope. Heavy rainfall may occur when the land is without a crop. Consequently the amount of water running in the channel may be very great and the risk of damage is increased. In such an instance solid sodding, the most effective means of protecting the channel, is needed.

The soil type of the channel under construction may be loose (of a sandy type) or may be compact (of a clayey type) and the method of vegetating must be adjusted accordingly. Sandy soils need more effective means of protection than the clayey soils. Four different methods of establishing vegetation have been used in the Mayaguez area: These are (1) solid sodding, (2) strip sodding, (3) sprigging, and (4) strip sodding and sprigging combined.

Solid sodding.—When this method is used a continuous cover of grass sod is transplanted over the entire bottom of the channel and about one foot of the channel sides. When enough grass is available solid sodding is recommended. In the Mayaguez demonstration area it has been used in channels constructed on slopes of more than 40 percent with estimated velocities exceeding 8 cubic feet per second. Some of these channels were constructed during the rainy season, and the run-off water had to be diverted to a temporary channel until all the vegetation had become established. In other places, however, wire netting was used to hold the sod.

The sod had to be dug by hand with long-handled spades, as there was no sod-cutting machine available. We think, however, that it is unlikely that a sod cutter will work in most of the areas in Puerto Rico, as there are practically no large areas of flat pasture land in the interior of the island where most of the solid sodding is being done.

The results obtained in more than 25 solid-sodded channels were very satisfactory: In more than 90 percent of them erosion of channel bottoms was prevented even when the rain intensities, several times recorded, were over 3 inches per hour for a 5-minute period.

Strip sodding.—This system involves trenches dug across the channel with a definite vertical interval. Care must be taken that the trenches are cut to the dimensions of the sod blocks, so that they fit in flush with the bottom of the channel.

In the beginning of our work we were using strip sodding in channels constructed on slopes of more than 20 percent, but we noticed that small overflows developed below each strip of sod. This showed us that strip sodding may not be recommended for chan-

[1] Principal agronomy aide, Puerto Rico Reconstruction Administration, San Juan, P. R.

nels constructed on steep slopes and should be used only in places where scarcity of grass makes it difficult to obtain enough for soild sodding.

Sprigging.—Sprigs are planted in small holes about 1½ inches in diameter and 2 inches deep, usually made with an iron bar, or with a sharp-pointed stake and a hammer, in the bottom and sides of the channel. The holes should be spaced about 8 inches apart each way and staggered. In order that the sprig will have a good start, the hole must be filled with a mixture of good topsoil, "cachaza" (a sugar mill byproduct) and mixed fertilizer.

The slopes where sprigging is used to advantage are not steep ones. The method is economical and the channel bottom will be covered very rapidly, especially if Bermuda grass is used.

Strip sodding and sprigging combined.—We noticed that small overfalls developed below the strips of sod, and to correct this the eroded places between the strips were filled with soil which was tamped and sprigged with the same kind of grass as that growing in the strips. By this method coverage of the channel was accomplished more rapidly than where strips alone were used, and there was less erosion between strips. Where sod is scarce, strip sodding may be used satisfactorily on steep slopes, providing the spaces between the strips are treated with sprigs. However, this is not to be recommended for use in channels with slopes exceeding 25 percent.

Most of the grasses that have been tested in the Mayaguez area are proving satisfactory for soil-erosion control and vegetative protection of outlet channels. Among those already tested are Bermuda, centipede, and carpet grass.

Bermuda is a rapid-growing grass during rainy periods, but when a dry period starts, it suffers greatly from lack of water. It does not thrive in shade. It is recommended for use in sprigging because of its rapid growth under favorable conditions.

Centipede grass is slow growing and is especially adapted to a shady, moist condition. Good results were obtained from solid sodding with this grass. When planted during dry periods mulch can be used to advantage. Sprigging with this grass should be avoided because of its slow growth. If sufficient centipede grass is not available for solid sodding, chunks of sod about 2½ inches in diameter may be used; they must be watered and covered with mulch. Once established, centipede grass, because of its low growth and dense cover, is one of the best species.

Carpet grass does better in shady and humid locations than any of the other grasses tested. It is scarce in the lowlands, however, while in the highlands it is abundant. Its use in dry locations should be avoided. It has a low growth habit and should not be stimulated to tall growth by use of too much fertilizer. It should be kept in mind that when the channel is treated, the sides must also be protected. Mainly, we use the sprigging method.

RIO GRANDE DE LA PLATA

(Continued from p. 11)

channel-type terrace is recommended for water interception and diversion and as a guide for contour tillage. A variable channel gradient, and a vertical spacing dependent on slope to a maximum 6-foot spacing, are used in layout work. The main objection to this method of terracing is the inevitable problem of satisfactory maintenance, as in the Cayey area there are no suitable plows for proper plowing.

Group 8.—In this group are all riverwash soils near streams for which only native pasture can be recommended because of subjection of such areas to overflow by the streams. Where streambanks are likely to slough and cut back, bamboo plantings on the contour are stipulated for protection.

Strip cropping is recommended where practicable on all cultivated slopes, with alternate bands of clean-cultivated row crops and thick-growing crops to eliminate overloads of surplus water and soil flow on barriers and other structures. Peculiar to Puerto Rico is the fact that thorough utilization of the land necessitates the use of food cash-producing crops, whether clean-tilled or close-growing in the strip cropping system. There is little likelihood of satisfactory adaptation of purely green-manure or leguminous crops in the agriculture on subsistence farms of the size held by resettlers. Sodded concentration, or outlet channels, are essential in bench formation and channel-type terraces for disposal of surplus surface water. Crown cultivation only is recommended for bananas, plantains, and fruit trees, with undisturbed areas left between plants and tree.

Individual bench terraces for grove plantings of fruit trees are being used and recommended. The plantings are contourwise; i. e., all benches on a row of trees are level or on the same contour. Up and down the slope, the individual benches are staggered. Each tree occupies the center of an individual bench terrace which extends radially from the tree, approximately horizontally, for at least 2½ feet. Crown cultivation is stipulated, and the area between benches is recommended to remain well covered with cover crops or native vegetation.

Panoramic view of tillage experiment on bench terraces. To determine effects on drainage, plots with ridging in various directions are being prepared. This Puerto Rican type of bench terrace provides drainage by having a higher outer edge and a low grade at the inner edge, along which the water is carried to a sodded outlet.

TILLAGE TESTS ON BENCH TERRACES OF MUCARA CLAY

By ROBERT L. DAVIS [1]

BENCH terracing has been advocated as a method of controlling erosion on steep cultivated slopes in Puerto Rico. The bench terrace of Peru and the East Indies has a low dike built along the outer edge to facilitate irrigation and protect the banks, but the type used in Puerto Rico [2] differs in that it was designed to meet requirements in the island where one of the main problems is drainage. In the Puerto Rican bench terrace no dike is used, but the outer edge is somewhat higher than the inner edge and thus drainage is ensured and water is prevented from running over the terrace bank. An open ditch along the flow line, or inner edge of the terrace, drains the water into a sodded outlet channel. As it was early apparent that no literature was available on suitable methods of cultivation on bench terraces of the Puerto Rican type, tillage tests were initiated and carried out to secure the data needed. This article describes these tests.

A 1-acre field of bench terraces on Mucara clay with a slope range of 20 to 35 percent was selected for trial. As originally constructed the terraces had a vertical interval of 4.5 feet and a grade of 3 inches per 100 feet. They did not drain well, however, apparently because no provision had been made to increase the carrying capacity of the terrace at the narrow places. This defect was corrected in October 1938, by increasing the greater height of the outer edge of the terrace to 12 inches. It resulted in a back slope of about 4 percent at the broad places and 10 percent at the narrow places.

Three directions of ridging designed to facilitate drainage and check erosion were compared with flat cultivation. The tests involved ridges parallel to the outer edge of the terrace, and ridges at 10° and 45° angles to the inner edge of the terrace. The photograph illustrates the Puerto Rican type of bench terrace and shows ridges being constructed at various directions to determine their effect on drainage and on holding soil moisture. The plots varied considerably in size because of the variable width of the terrace bench, but they averaged one twenty-fifth acre in area. There were five plots of each treatment and one of each treatment was located on each terrace.

All ridgings reduced the row slope and thus tended to hold the water on the terrace benches. A ditch at right angles to the terrace bank was provided at the

[1] Agronomist, Soil Conservation Service, U. S. Department of Agriculture, Mayaguez, P. R.

[2] Designed in August 1936 by George L. Crawford.

Soil moisture percentages and corn yields in tillage tests on 25- to 35- percent slopes of Mucara clay at Mayaguez, P. R.

Cultivation practice	Plot group numbers					Average miosture	Average ** yield of corn
	1	2	3	4	5		
	Soil * mois-ture	Soil moist-ture	Soil mois-ture	Soil mois-ture	Soil mois-ture		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Bushels*
Flat cultivation	29.01	33.92	31.79	27.47	32.00	30.84±2.08	52.78± 6.31
Ridges parallel to terrace crown	31.12	34.38	26.75	28.54	32.89	30.74±2.47	55.79±12.90
Ridges at 45° angle to the flow line	28.74	33.00	38.50	31.58	31.60	32.68±2.45	58.80±11.12
Ridges at 10° angle to the flow line	26.48	29.31	28.51	27.95	28.08	28.06± .68	65.36±18.71

* Moisture determinations are based on a composite soil sample from 5 borings per plot, made to a depth of 6 inches on the westward sides of the ridges, 4 feet from the outer edge of the terrace and halfway between adjacent hills of corn.

** Yields of air-dry shelled corn are based on harvests of 1/100-acre areas taken from each plot. The yields given are those of the actual area occupied by the corn, not including the terrace bank. The corn was harvested by L. Valdespino and Juan Pérez, of the Puerto Rico Reconstruction Administration.

lower end of each plot to prevent drainage of any plot from affecting adjoining plots. When ridges parallel to the flow line are used on terraces several hundred feet long, ditches of this kind are essential to prevent too much water from accumulating during rainy periods.

With the object of securing economy in land use, all ridges were spaced 2 feet apart. Where the terrace width did not permit of an even division, wider spacing would have resulted in considerable unused land at the edges. Plantings were made on the westward side of the ridges so that they would be protected against the drying effect of the prevailing wind and the morning sun. They were placed halfway down the ridge in order that the plants might be on the same level as those grown on the plots given flat cultivation.

Although plot sizes were not large enough to give full advantage in using the plow, sharp contrasts were noted in cost of land preparation and cultivation. Since the ridges at the 45° angle to the flow lines were very short they were constructed by hand at a cost of $16.32 per acre, which is probably prohibitive for subsistence crops. The other ridges were plowed out with a mule and 7-inch hillside plow, and the only handwork was that done in opening up the lower ends of the furrows. The construction of those parallel to the outer edge cost $5.94 per acre, while those at the 10° angle to the flow line cost $3.20. The accurate spacing of the ridges, which would not be necessary under ordinary farm conditions, ran up costs unduly for the ridges parallel to the outer edge; ordinarily they would cost less than those made at 10° angles, as there would be fewer furrow ends to finish by hand.

All ridging apparently reduced soil loss. In plots without ridges the water drained off rapidly and was observed after the heavier rains running in small streams almost straight down the slope to the inner edge of the terrace. In plots with ridges the planting furrows were often full of water for some minutes after rain had stopped. Ridges at a 45° angle to the flow line reduced the drainage slope but slightly, and there appeared to be more rapid silting in the lower ends of the furrows than on the plots where the more gently sloping ridges were used. Drainage was good on all plots, and within an hour after rain practically no standing water was observed.

A severe winter drought resulted in depleted stands of all plantings made in the fall of 1938. In April 1939, the ridges were restored to their original height by hoeing and were planted to field corn. The hills were 3 feet apart in the row and the corn was thinned down to two plants to the hill, thus allowing 3 square feet per plant. Conditions were favorable and an almost perfect stand was secured. Acre rates of fertilizer applications amounted to 600 pounds of the formula 8–14–4 (ammonium sulphate, calcium super-phosphate, and potassium sulphate), placed in the hills at planting time and an additional side dressing of 150 pounds of ammonium sulphate just before tasseling. The mixed fertilizer alone apparently was ample, as the corn had healthy dark green leaves and grew well over 8 feet in height, except on a few spots on the steeper slopes.

The weeding cost of plots given flat cultivation was lower, averaging $6.71 per acre—this because there was no ridging to interfere with the work of the mule. Plots with ridges parallel to the outer edge, the only others given mule cultivation, cost $7.75 per acre. Because of the risk of destroying corn plants when turning, mule cultivation could not be used on the rows at 10° or 45° angles to the flow line, and costs were therefore high, $8.60 and $9.16 per acre, respectively.

In studying the effect of ridging on holding soil moisture, determinations were made when the corn was about a month old and toward the end of a rather severe drought. These determinations are shown in

the table. The moisture in plots having ridges parallel to the terrace crown averaged 30.74 percent and in four of five comparisons was higher than in those given flat cultivation or those with ridges at a 10° angle. The moisture percentage averaged highest in plots having the ridges at a 45° angle, but this was because of the unusually moist condition of one plot at the lower end of one terrace. These results indicate that contour ridging on bench terraces might play an important part in ensuring good yields from fall plantings maturing in early winter when severe protracted drought is normal.

When the uncultivated areas of the terrace banks are included in the calculations, the average yield per acre was 43.2 bushels of shelled corn. This is the maximum yield reported for field corn in the Mayaguez district, except on small experimental plots. Fifteen bushels on unterraced upland slopes and 35 bushels on fertile lowlands represent good yields. The field used had been badly overgrazed and abandoned prior to terracing. The results indicate that bench terracing and heavy applications of fertilizer may reclaim land of this type and make it productive.

Plot yields as shown in the table were variable, and tillage treatments did not give significant yield increases over flat cultivation. If the drought that occurred when the corn was young had been more severe, the moisture-holding capacity of the ridging probably would have affected yields. The data represent yields or actual areas occupied by the corn, excluding that of the terrace bank.

Bench terrace construction usually exposes barren subsoil along the inner edges of the terrace near the base of the bank. To determine the extent to which soil building is needed, harvests were made at various distances from the terrace bank. In seven out of ten comparisons, corn grown 2 feet from the terrace bank yielded less than that grown at a distance of 4 feet. The average difference was over 8 bushels an acre. Contrasts were about as strong between yields at the 2-foot distance and those of 6- or 8-foot distances. There were no such yield differences between corn grown at 4-foot and that at 6- and 8-foot distances. This indicates the urgent need of green manure crops for soil close to the base of the terrace bank. Until it is rebuilt, this unproductive land which is about one-sixth of the cultivable area, may be considered as having been thrown out of cultivation by bench terracing.

Conclusions

Drainage was adequate on plots without ridging. This indicates that for drainage purposes the bench terrace design used is satisfactory and ridging unnecessary.

The use of ridging to conserve moisture may be desirable in fall cropping to minimize the effect of the winter's drought.

Cultivation costs are less with ridges parallel to the outer terrace edge than with ridges at 10° or 45° angles to the inner edge.

Construction costs for ridges at a 45° angle are probably prohibitive for subsistence crops.

Low corn yields 2 feet from the base of the terrace bank indicate the need for use of green manure crops.

The high average corn yield indicates that steep overgrazed slopes of the type used may be reclaimed by bench terracing and adequate application of fertilizer.

PASTURES IN PUERTO RICO

(*Continued from p. 18*)

tion. The closely interwoven fibrous root system of grasses in the surface soil, together with the herbage above the ground, spreads the surface run-off and prevents the formation of finger gullies. If water concentrates in slight depressions it is soon diverted and spread by other grass plants farther down the slope, thus reducing the velocity and allowing a large proportion to percolate into the soil as it moves slowly down the slope. Most of the silt that it may carry as it flows down the slope is held by grasses and grass residues farther down. The impact of the raindrops also loses most of its effect. The drops fall at high velocity on the vegetative part of the grasses and do not hit the soil directly. The surface soil particles are not loosened as readily as they are where there is no vegetative covering.

Most grass roots are found near the surface, though a small percentage penetrate to lower levels. When some of the surface soil is lost by erosion, the roots which penetrate to lower levels aid in forming new soil underneath from parent soil materials, and this helps to balance the soil lost on the surface by erosion.

A single issue of SOIL CONSERVATION manifestly cannot give complete treatment to the land-use and erosion problems and programs of Puerto Rico. From time to time, as space permits, additional articles will be published pertaining to the island's soil conservation activities.—Editor.

USE AND LIMITATIONS OF TRASH BARRIERS

By ROBERT L. DAVIS [1]

THOUSANDS of acres on steep upland slopes in Puerto Rico are being cleared for cultivation. Much of this land is covered with trees and bushes or, occasionally, a dense growth of grass. It is common practice to burn all the trash, but a more satisfactory disposal is to place it along the lines surveyed for terraces so that it can be used to support the soil plowed or cultivated downhill. Any stones found in the field may be gathered and included in the barriers and, if there is not enough trash, vegetation may be used. In any event, it is essential that some binder plant that roots at the joints be present so that it will grow over the trash and hold it together. Otherwise, after about a year, the barriers will collapse in the places where decay is most rapid and the soil held above them will be washed down the slope.

The making of trash barriers is a simple process once the survey is completed, even where the land is in forest. The larger tree limbs are used for firewood or in making charcoal; the smaller ones are placed in position and then made into a fairly compact barrier by cutting from above with a machete. Any leaves or smaller bits of trash are placed directly above to catch the soil, and below the barrier an occasional stake is driven in for support; on the steeper slopes the stakes are placed close together, one about every 3 or 4 feet. Where time permits, the planting of pigeon peas or Guinea corn at the proper places would make staking unnecessary and, no doubt, would lower costs. The tree stumps that are difficult to remove may be left to be worked out as they decay, and in the meantime the plow may be passed around them.

When the trash consists mostly of small tree limbs and brush and is piled up 1 or 2 feet high, it may form a stiff enough barrier to hold the plowed soil during the first year or two, provided vegetation is used to bind it together.

The photograph illustrates this type of trash barrier below which wild beans (*Calopogonium coeruleum*) were planted. The wild beans have taken root at the joints and are binding together the decaying trash. Terrace banks about 2 feet high have formed in about 18 months. The bank is now approximately on a level with the top of the trash. After this, unless more trash of the same kind is added, the barrier no longer will support a plow furrow slice. It becomes necessary, therefore, to plant stiff-stemmed plants, such as elephant grass, just above the barrier for the purpose of building the terrace bank still higher. If the plantings are not made and the plowman is careful not to throw the plowed soil directly against the trash barrier, but somewhat higher up the slope instead, the terrace bank will continue to form to a certain extent but will not be steep enough and will occupy too large a proportion of the land. Where there is not enough trash, the stiff-stemmed plants should be used from the very first.

In the case of hand cultivation the stiff trash barriers will hold the soil fairly well without stiff-stemmed plants, but as a rule there are two difficulties: It is not likely that the laborer will spread the soil uniformly or close enough to the barrier, to form a steep terrace bank; and furthermore, crop residues and other trash may not be spread uniformly next to the barrier so that breaks in the terrace bank will occur where the smaller amounts are placed. The use of the stiff-stemmed plants above the trash barrier tends to correct all this, as they provide a uniform obstruction that holds both soil and other accumulations all along the terrace line.

When the trash barrier is made of the ordinary kinds of native pasture grass, and consists largely of small weak stems and leaves, it is not rigid enough to support soil plowed against it. For this reason this kind of trash should not be used alone for constructing terraces; it can be used, however, in combination with stiff-stemmed forage grasses similar to elephant and Guatemala grass. Trash barriers of small weak stems can be used for making barrier terraces if construction work is done with care and by hand—that is, if the farm laborer very carefully hoes the dirt against the trash and takes great pains to form the right slope so that too much of the land will not be occupied by the terrace bank. This is an expensive procedure, however, and should be used only when the trash contains considerable amounts of living sprigs from grasses such as Bermuda and sour Paspalum which would take root in the soil and form a living protective cover. Care would be needed also in arranging sprigs uniformly along all the terrace banks. Should the trash consist entirely of dead material, it would be necessary to plant grasses of the above mentioned type in it [2]; otherwise it would be certain to decay and the terrace

[1] Agronomist, Soil Conservation Service, U. S. Department of Agriculture, Mayaguez, P. R.

[2] Bermuda grass practically doubles cultivation costs, and should not be used in localities where it is not already prevalent.

Barriers of leaves, brush and small limbs. Wild bean vines have taken root in the decayed trash. Scene: The Marini farm near Mayaguez.

bank, no longer protected, would be quickly destroyed by the heavy tropical rains.

Near Cayey, trash barriers containing living sprigs of Bermuda grass have been used extensively above hillside ditches. Where Bermuda grass was sufficiently prevalent, they were effective in filtering out the soil washed down the steep slopes between the ditches. Data gathered from similar slopes, or the same slope above one ditch, are given in the table. Where trash was available, or uniformly distributed above the ditch, soil accumulated to a depth about 6 to 14 inches greater than where trash was not used. With one exception, however, the bank slope was not steep enough for economical use of the land. On a good many farms in the same vicinity it was observed that the trash had been dried out and burned or, if retained, was not placed properly; this is but one example of the difficulties encountered in trying to instruct the farmers in the use of material of this kind. Stiff-stemmed plants, planted at about the time the ditches were constructed and just below the trash, would have ensured better protection as well as better bank development.

It is apparent in Puerto Rico that in no case is it practical to use trash for barriers without living plants to hold it together as it decays. The use of stiff-stemmed barrier plants cannot be avoided unless all the work is done by hand, and this would require expensive supervision to ensure uniform development of the terrace bank.

Terrace bank formation resulting from use of trash above hillside ditches at Buena Vista farm in the Cayey area of the Soil Conservation Service

Number of resettler farm	Soil type	Slope percentage	Direction of exposure	Cultivation practiced	Bank * slope percentage	Bank height *	Trash disposal
		Percent			*Percent*	*Inches*	
33	Jacana	27	Southern	Plowed 3 times	80.7	23.7	Trash raked off field.
** 38	Mucara	30	do	do	121.4	30.2	Trash uniformly distributed.
32	do	25	Northern	Plowed 3 times and hoed twice	90	22	No trash.
32	do	25	do	do	118	39.2	Trash lined evenly.
40	Jacana	28	Southern	Plowed once and hoed twice	119	28.4	No trash, banks badly eroded.
40	do	28	do	do	165.8	36.8	Trash lined evenly and banks protected with Bermuda grass.

* Averages of 5 measurements in each case made with a clinometer and ruler. Data were gathered on September 8, 1939, by Carlos Archeval, agronomy aide of the Puerto Rico Reconstruction Administration.

** Most of the cut in resettler farm 38 consisted of parent rock material. The bank above the ditch was bare as trash was all dead and lacking in any stoloniferous plants.

AN ATTEMPT AT WATER SPREADING IN PUERTO RICO

By R. C. CLIFFORD [1]

TOWARD the center of the southern coast of Puerto Rico, more specifically around the town of Coamo, lies a great deal of country that is used for cattle raising. Here the land is mostly in pasture and although there are a few dairy farms the raising of beef and work cattle is the major industry.

Near the coast, the land flattens out into large plains on which the major crop of the island, sugarcane, is grown exclusively. Farther back, and some 7 or 8 miles towards the north, steeply sloping hills close off this part of the south coast from the rest of the island. The cane belt lying along the coast to a depth of 3 miles is irrigated from canals which convey water from two large reservoirs. Lying between the cane belt and the lower hills of the range to the north is the pasture country. This land is in pasture merely because it cannot be reached by irrigation water and the rainfall is not sufficient to make cane farming a successful enterprise. The pasture land lies within a rain belt averaging 34 inches a year.

The general topography may be described as rolling with small isolated hills rising here and there. The slopes vary from 5 to 15 percent on about a fourth of the pasture lands; on about half the area the slopes range from 15 to 40 percent while on the remainder they are from 40 to 60 percent and more. The hills are very sparsely wooded and their lower slopes are planted to pasture grass. A few scattered farms, hanging to the hillsides, eke out a precarious existence.

[1] Engineer, in charge, soil conservation work at Coamo and Sabana Grande, P. R.

The soils of the pasture land on the lower slopes consist mostly of Coamo and Yauco clays to clay loams. Both these soils absorb water readily but they are well drained and have a semifriable subsoil.

Much of the pasture land has been planted to Guinea grass which, during the rainy period or more specifically from August to the end of November, grows almost high and dense enough to hide the pasturing animals. The grass is grazed while still green and until about the middle of March. This grass needs a great deal of moisture to keep it green and during the hot and dry summer months the pastures appear brown and burnt with no trace of Guinea grass showing. Should there be a dearth of moisture during the rainy period, the farmers lose many cattle; in the summer of 1938 one cattle farmer lost 80 head and another 72 head from lack of feed. The cattle farmers estimate that 3 acres of good pasture will carry one cow a year. It is their opinion that during the months when there is no Guinea grass, the native grass and weeds will carry the cattle over until the Guinea grass revives—that is, if the rains are normal.

Generally speaking, the rains in the hills exceed those that fall on the lower lands. With this in view, and with the purpose of utilizing the extra rainfall run-off from the hills, to augment the moisture on the lower and flatter lands, the Coamo water-spreading project was undertaken as a demonstration. The project area consists of about 80 acres, and as a demonstration area it is ideally situated; it lies along a paved and well-traveled highway which connects San Juan and Ponce, and is only about 3 miles from the town of Coamo. The area lies north of the highway and is bounded on the north and west by the lower slopes of hills that form part of the range to the north of the pasture lands. At one time this land was planted to cane but lack of moisture made cane farming unprofitable and it was converted to pasture. Tufts of Guinea grass were planted along the old cane furrows but without very good results, as Guinea grass density is only about 25 percent. Native wiregrass and small weeds constitute the major cover. The average slope is 5 percent over most of the area and the soil is a Coamo silty clay loam. The land is flat to gently rolling with two distinct drainageways which unite toward the lower end of the area and form a medium-sized gully. Run-off from the north is intercepted by a gully which runs between the hills and the area and parallels the north boundary fence, while the hills along the west boundary shed their run-off directly on to the pasture land. The gully to the north has a watershed area of 85 acres of steeply sloping, sparsely wooded and well-grassed hilly land.

In computing the run-off the commonly accepted intensity for a 25-year period, 8 inches, was used with a run-off factor of 0.5, which gives an expectancy of 340 cubic feet per second. The normal amount of precipitation in this region is 3 inches, and this may be expected once or twice a year, generally following rains of lesser amount. The average rainfall and average run-off figures of the Coamo Reservoir report, covering a period of 30 years and made by the Puerto Rican Irrigation Service (south coast), show that the greatest run-off may be expected in the month of November. As these are the only figures available, they were used in computing the run-off that may be expected from the 85 acres of watershed. It was found that during November the run-off from a 3-inch rain would be approximately 10 acre-feet.

In order to utilize the water coming from the 85-acre watershed it was necessary to construct an earth dam and divert the water to the spreading ground. An earth dike, connected to the dam, conducts the water out across the upper portion of 30 acres of spreading ground. Placed in the dike are five weeps, through which the water is spilled on to the plain below the dike. A spreader has been placed at a vertical interval of 2 feet below each weep. These spreaders consist of two rows, 4 inches apart, of Merker grass. In constructing the spreaders, two parallel furrows were made and the soil thrown to the center was used as a seedbed. The spreaders are V-shaped and placed on a 0.4-percent grade. Other spreaders of Merker grass at 2-foot vertical spacings have been placed on a grade, and the water has been sirup-panned over the 30 acres lying below the dike.

The run-off from the hills lying to the west of the area also has been diverted from its original waterway by means of an earth dike and is now conducted to a fairly smooth spreading area. Weeps have been placed in this dike, with Merker grass spreaders below them. An attempt has been made to increase the density of the Guinea grass by plowing and seeding alternate interspreader spaces. The part of the area that cannot be reached by spreading has been furrowed on the contour. Four furrows have been made with ox-drawn plows at intervals of 2 feet vertically; these have been seeded to Guinea grass. The small gullies in which water might concentrate have been checked by four-row plantings of Merker grass placed crosswise of the gully. The checks are V-shaped so that they will not only check the flow but also divert it out of the gully. The V-arms extend for 25 feet on the banks.

(*Continued on p. 30*)

SOIL CONSERVATION IN SUGARCANE

By ROBERT E. WITHERELL [1]

ON THE second voyage of Columbus, sugarcane was brought to Hispaniola, or, as it is now called, the Dominican Republic. The first sugar was made in 1509. From this island as a center of distribution, cane soon reached Cuba, Puerto Rico, and other West Indies. The first sugar mill in Puerto Rico was established in 1524. All of these early movements of cane, both in Europe and in the Western Hemisphere, had to do with one single variety. This was a short-jointed, medium slender, greenish cane of poor tonnage, but with sweet juice and soft tissue that made it easy to mill and pleasant to chew. The early cane was replaced during the later years of the eighteenth century by better and more productive kinds. From this time on, the history of the cane-sugar industry becomes more and more a history of the introduction and distribution of cane varieties, such introduction usually being the result of an outbreak of disease that seriously threatened local industry.

A variety of cane known as Otaheite became an universal favorite and its extensive planting really marked the beginnings of the modern sugar industry. For many years after its introduction, this Otaheite cane continued to grow vigorously and yield abundantly. However, it was found after the first richness of the soil had been exhausted by continued plantings, or when plantings had been made on poorly adapted soils, that production was rapidly decreasing.

In 1872 a disease appeared in the Otaheite cane on the east coast of Puerto Rico. It so happened that the outbreak was first noted on the farm where the Federal Experiment Station is now located at Mayaguez. It soon spread until the western half of the island was involved. In the infected fields the cane was short and stunted and soon died. Here and there, scattered among the Otaheite variety were stools of Chrystalina cane and it was noted that they were but little affected by the disease so that this hardiest kind was chosen and the industry was restored.

Again in 1915 an unknown and mysterious disease appeared in the town of Arecibo and extended into the hilly section to the west of the town. Its effects on the cane caused a stunting of the growth while the leaves became mottled or chlorotic in appearance. It was considered as something new and was called in Spanish "matizado," the name by which it is still generally known in Puerto Rico. The disease spread rapidly and in 1918 had invaded practically three-fourths of the sugar area of the island.

In August 1918, Prof. F. S. Earle was commissioned by the United States Department of Agriculture to go to Puerto Rico and investigate the disease, in cooperation with the Federal and Insular experiment stations. Important headway was made and the mysterious "yellow stripe" was found to be identical with the mosaic of Hawaii and the "Galestrepenziekte" of Java.

Up to this time the sugar production of Puerto Rico had not exceeded 500,000 tons, and it was believed that it would never again reach that figure. In 1919 it had fallen to less than 400,000 tons and there were practically no new lands to be brought into cultivation. As agricultural methods improved, by 1925, the presumably worn-out cane land was made to produce 660,000 tons. However, the methods of improvement consisted of new cane varieties and the increase in application of fertilizer with different formulas.

Improvement in the manufacturing side of production had gone forward rapidly, as had methods of transporting the cane to the mill. In recent years steam plows and gasoline tractors have been used more and more widely for preparing the lands, but the furrows with few exceptions still ran straight up and down the hill and little thought was given to channel design. The heavy rainfall during the planting season exacted its tremendous toll from the soil. No great thought had been given to erosion or soil loss, and it was not until 1936 when the Soil Conservation Service of the United States Department of Agriculture sent a small group of technicians to the island that one of the most important cultural changes slowly began to take place. With the cooperation of the Puerto Rico Reconstruction Administration funds were made available to carry out demonstration and research work in soil conservation practices.

Studies are now being made at the Soil Conservation Experiment Station at Mayaguez on the contour cultivation of sugarcane. At the demonstration areas located at Castañer and at Zalduondo Farm, Luquillo, comparisons are being made to determine, under field conditions, the advantages of contour furrowing and ridge terracing over the usual methods of cane planting.

At Zalduondo Farm, 4 acres were selected on slopes ranging from 5 percent to 33 percent on the poorest land in the area. The field was plowed and harrowed

[1] Agricultural engineer, formerly in charge, Viequez and Luquillo areas, Puerto Rico; now agricultural engineer, Everglades project, Soil Conservation Service, Fort Lauderdale, Fla.

Hillside ditches being constructed by oxen, near Mayaguez.

in the usual way for cane planting. Ridge terraces were staked out, opened with a hillside plow and then cleaned with ditching spades. Three different falls were used in laying out the furrows, namely, 1 percent, 1½ percent and 2 percent.

Five furrows spaced 3½ feet apart were made on a 1-percent grade, five furrows 3½ feet apart on a 1½-percent grade and five furrows 3½ feet apart on a 2-percent grade. This series of furrows was continued down the slope until the field was completed. Between every alternate five rows a ridge terrace was made with the same grades as the furrows. A spacing of 37 feet between each ridge terrace was allowed to intercept the run-off from the area between each five furrows. A terrace outlet channel designed to take a maximum intensity of 8 inches per hour was constructed and properly sodded with Bermuda grass. The furrows and ridge terraces acted as individual ditches to carry the rain that fell on the field into the main outlet channel.[2] This type of construction eliminates the customary practice of making small ditches down the hill and breaking the furrows when heavy rains occur; thus it prevents soil and fertilizer loss and at the same time conserves moisture.

The field was planted on April 24, 1938. One cane seed to the stool, of the P. O. J. 2878 variety, was planted in the furrows in a single row instead of the usual double row planting. This method reduced the seed cost by 50 percent. No fertilizer was applied until the cane was 2 months old; then 10 hundredweight per acre was used. The cane closed very quickly and only 4 cleanings were necessary as compared to the 6 or 7 required by the Puerto Rican system.

At the age of 5 months, the cane reached a height of 9 feet. On September 15, 1938, the grades of each furrow and ridge terrace were checked. Where the slope of the land was 33 percent only a small group of the furrows with the 2-percent grade had changed to approximately 1¾ percent. Part of this change was due to silting and part to earth falling in from the furrow ridge. It should be added that the day after the cane was planted, a rain of 9 inches in 5 hours was recorded. No damage was done to the furrows and the ridge terraces drained perfectly with only a slight silting.

In November 1938 when it was 8 months old approximately 60 percent of the cane arrowed. On May 6, 1939, when the cane was 12 months old 0.4 cuerda (0.97 of an acre) was cut. The small plot from which the cutting was made was one of the poorest parts in the entire field. The cane was shipped to Central Fajardo and according to their records the plot produced 14.61 tons of cane with an analysis of: brix 21.5; purity 85.7; sucrose 53.84. The yield for this field was 36.52 tons per cuerda.

Immediately after the plot was harvested the trash was lined, one cultivation was given, and 200 pounds of fertilizer was applied. While it is too early to make definite statements regarding the advantage of this type of cultivation as compared with the usual planting methods the following advantages are listed as probable:

1. Less seed will be required to obtain a complete stand of plants,—this because of the retention of more moisture in the field and the prevention of soil and fertilizer loss.

2. Four weedings only were given to the field because the cane closed quickly. This compares with 6 or 7 weedings normally given in this region.

3. Although the poorest part of the field was cut, it produced 36.52 tons per cuerda (spring cane) as compared with an estimated 30.33 tons per cuerda produced on the adjoining slopes. It is reasonable to assume that had the entire field been harvested it would have produced about 40 tons per cuerda.

4. This method of planting aids considerably in preventing the falling or breaking down of cane and thus reduces damage due to rot.

5. The first ratoons (regrowth) are a favorable indication of the advantage of this system. These ratoons closed with only two cultivations and in 2 months reached a height of 6 feet.

6. Contour cultivation conserved the moisture; the rainfall during these 2 months was 9.29 inches which, compared to the same 2 months of 1938, is less than half.

This preliminary experiment shows clearly the great need for a much more comprehensive knowledge among the sugar growers of soil conservation practices. Every effort is being made by the Service to aid them.

[2] Soil Conservation Service rainfall records show that in this area on April 25, 1938, 9 inches fell in 5 hours.

TRAILING INDIGO, A PROMISING LEGUMINOUS FORAGE PLANT

By ROBERT L. DAVIS and BERNARDO FIOL VILLALOBOS [1]

MANY leguminous plants are being introduced by the Soil Conservation Service Research Station at Mayaguez. Some of them have already been discarded as not adapted to our conditions while others are still under observation. Among the latter is trailing indigo (*Indigofera endecaphylla*) which spread more rapidly than any other legume in the preliminary tests made during the year 1937. It is considered promising as a forage and erosion-control plant for Puerto Rico. This article deals with a series of observations made on trailing indigo at the Soil Conservation Service Research Station at Mayaguez.

Trailing indigo (*Indigofera endecaphylla*) is a legume belonging to a large herbaceous genus, well distributed over all the tropics and common in rather dry climates. It is an annual or biennial trailing herb found throughout the tropics of the Old World. It is subject to root diseases in humid locations and is apt to wilt and suffer from inadequate formation of root nodules.[2]

Seeds imported from the island of Ceylon were planted on October 4, 1938, on Catalina clay lowland. In order to obtain a good germination, they were treated with a 50-percent solution of sulphuric acid for 25 minutes and then soaked in water for 24 hours. They were planted at a distance of 18 inches between rows and about 5 inches between spots, using 6 to 8 seeds per spot. This was at the rate of about 5 pounds per acre. Two weedings were given during the first 90 days when the plants were small. Growth closed in during the fourth month and required no further attention. This indicates that trailing indigo will compete with the common weeds of the island, with the possible exception of malojillo (*Panicum purpurascens*) which outgrew it, and green cohitre (*Commelina elegans*) which survived competition underneath the mat of trailing indigo stems.

In August 1939, 10 months after planting, samples were gathered to determine the probable erosion-control value of trailing indigo. The results of observations are given in table 1.

TABLE 1.—*Counts and measurements per square foot of ground surface made on trailing indigo 10 months after planting (Aug. 8, 1939)* *

Samples	Leaves	Area per leaflet **	Total stem length	Stem diameter	Maximum possible interception area		
					Leaves	Stems	Stems and leaves
	Number	*Square inches*	*Feet*	*Inches*	*Square feet*	*Square feet*	*Square feet*
No. 1	767	....	300	0.103	9.20	2.57	11.77
No. 2	651	....	306	0.090	7.81	2.29	10.10
No. 3	625	....	258	0.080	7.50	1.72	9.22
No. 4	625	....	228	0.080	7.50	1.68	9.18
Average	667	0.212	274	0.088	8.00	2.06	10.06

* Data gathered by William López, principal agronomy aide of the Puerto Rico Reconstruction Administration.

** Average found from 100 leaflets measured. An average of 9 leaflets per leaf was found by counts of 100 leaves. Stem diameters are averages for 10 stems.

As noted in the table this plant, in 10 months' time, will produce over 600 leaflets per square foot of ground surface. This furnished a protective cover of about 8 square feet for each square foot of land planted. Hence, most of the raindrops are caught by the foliage and do not strike the ground directly. Furthermore, there were nearly 300 feet of stems per square foot of ground; most of them occupied approximately a horizontal position and thus gave additional protection. The apparent protective value of trailing indigo at this time compared well with that of Bermuda grass growing in the same field. The average length of internode was 2.5 inches, and there were 33 primary roots per node and 1,284 nodes per square foot. Since about one-third of the internodes or 428 per square foot were rooted, it is calculated that there were over 14,000 primary roots protecting the soil on each square foot of the field. This is over 10 times as many as were found in Bermuda grass sod in an adjoining field of the same soil and constitutes another indication of its probable value for erosion control on steep slopes.

According to Burkill, trailing indigo has been used as green manure in Ceylon, where it was effective in preventing erosion on tea estates and in conserving or even increasing soil fertility. Its use under tea plants indicates that it will withstand considerable shade.

Trailing indigo has long been used as a forage plant in the East Indies. As reported by Burkill, the leaves and stalks when tender and succulent are readily eaten by cattle, although the plant will not stand heavy grazing. The oxen at Mayaguez ate it readily. With its succulent foliage and great number of small bright-green leaflets, trailing indigo resembles alfalfa. In

[1] Agronomist of the Soil Conservation Service, Puerto Rico Division, and agronomy aid of the Puerto Rico Reconstruction Administration.

[2] Burkill, I. H. A Dictionary of the Economic Products of the Malay Peninsula, 1935.

forage production it apparently compares well with molasses grass (*Melinis minutiflora*); on a 1/20-acre plot it produced 8 tons of green forage per acre when 8 months old. Average length of stem was found to be 7 feet and 8 inches which was the approximate spread during a 10-months' period. It grew on top of the native grasses and formed a dense mat with numerous succulent stems. Three months of this period were very dry and the surrounding grasses suffered severely, while the trailing indigo remained green and healthy. These observations indicate that it would do well in contour pasture furrows.

As a stock feed it seems to have a high value as shown by the following chemical analysis made by Dr. D. H. Cook of the School of Tropical Medicine of the University of Puerto Rico:

TABLE 2.—*Analysis of trailing indigo (Indigofera endecaphylla) made June 8, 1939*

	Calculated on a wet basis	Calculated on a dry basis
	Percent	*Percent*
Moisture	78.50	....
Crude protein	4.21	19.56
Ether extract	0.93	4.33
Crude fiber	5.86	27.24
N-free extract	10.29	39.04
Ash	0.21	9.83
Calcium	0.297	1.38
Phosphorus	0.0439	0.0204
Total solids	21.50	....

A test has also been made, on Mucara clay, to determine the cost and effectiveness of propagating by seed and cuttings. In this test the use of five seeds, one cutting and two cuttings per spot, were compared in triplicate on 1/20-acre plots. All spot plantings were made at intervals of 3 feet on contour ridges spaced 2 feet apart. The average percent of stand, as determined from counts made 9 and 18 days after planting, is given in the following table:

TABLE 3.—*Average percent of stands obtained by sexual and asexual propagation of trailing indigo*

Method of propagation	Stands on dates given	
	First count (Oct. 4, 1939)	Second count (Oct. 13, 1939)*
	Percent	*Percent*
By seeds	58.2	58.2
One cutting	66.8	51.3
Two cuttings	85.1	77.9

* The first period, from Sept. 26 to Oct. 4, had an average daily rainfall of 0.526 inch and the second period, October 4 to 13, had an average daily rainfall of 0.082 inch. The counts are averages of three plots in each case.

Better initial stands were secured from both the one cutting and two cuttings per spot than from seed. It should be noted, however, that the stand from seed was not reduced at the end of the 18-day period, while in the case of cuttings there was about a 10-percent mortality. This mortality was attributed to dry weather. The planting cost per acre, although only $2.10 in the case of seeds, averaged $9.04 for cuttings.

An average of 302 cuttings was obtained from a square yard at a cost of about 97 cents, which indicates that this kind of planting material is inexpensive and that the high costs involve mainly the hand labor used in planting it.

A Few Conclusions

Trailing indigo seems adapted to dry conditions at Mayaguez and will probably withstand the long winter's drought.

It probably will compete successfully with all common weeds of the island with the exception of malojillo and possibly green cohitre.

As an erosion control plant it seems very promising because of its numerous roots along both nodes and internodes, and because of its dense mat of stems and leaves which seem to compare well with that of Bermuda grass as a protective cover.

AN ATTEMPT AT WATER SPREADING

(*Continued from p. 26*)

The area has been fenced and all stock has been permanently excluded.

The project has been worked cooperatively with the owner, who has supplied cement, barbed wire and posts for the fencing, and Guinea grass seed, and has lent oxen and plows for the work. The method of treatment and also the structures have been kept as simple as possible so that they represent merely a labor outlay. This has been done with a purpose, as the project is a demonstration and may be imitated by other farmers at very little cost. The added moisture should not only increase the density of the grass cover but should tend to keep the pasture green over a more extended period. Stock farmers think that, while 3 acres of pasture is required for each cow, enough feed can be cut from 1 acre of cultivated pasture to feed 3 cows. More cultivated pastures do not exist in this region merely because there is no assurance of sufficient moisture to make pasture cultivation worth while. This water-spreading project which, after all, is also a flood irrigation project, may point the way toward overcoming the shortage of moisture and the conversion of more native grass pastures into cultivated pastures. The demonstration is being very closely watched by neighboring stock farmers and we have had many requests for Merker grass seed for source-bed planting.

SOME PUERTO RICAN SOILS AND THEIR USE CAPABILITIES

By JORGE J. LANDRON [1]

IT IS a well-known fact that there is great variability of rock formation, climate, and vegetation in Puerto Rico. The soils, which are the product of time and weathering interaction between these factors, are no exception to the rule. According to preliminary reports and information, about 374 types and phases under 120 soil series have been mapped. These figures show extreme variability of soil conditions for an island only about 4,000 square miles in area.

A soil survey of Puerto Rico has been made by the Bureau of Chemistry and Soils (now the soil survey division of the Bureau of Plant Industry) in cooperation with the Rio Piedras Insular Experiment Station. Although the final map and report have not yet been published, we have been well supplied with preliminary reports and maps and the information set forth in the 1938 Yearbook of Agriculture. In carrying on our conservation erosion surveys we have correlated our field work with the soil survey findings on the island.

On the island there are two broad divisions of soils. Those on the north side of the divide, where rainfall is high in most places, usually are referred to as north coast soils. Here the soils are leached, and the majority are Lateritic (Pedalfers) while on the southern part where rainfall is low the soils are less acid or alkaline. On the southern coast, foothills, and inner plains, we find the Pedocalic soils, Chernozem, Chestnut, Prairie, Brown, and others of the great soil groups of the world in scattered areas. Altogether there are about 21 great soil groups represented in Puerto Rico; probably there is no State in the Union having such a broad range.

On the western coast there is a serpentine formation extending east of Mayaguez, about 20 miles in length and averaging 2 miles wide. This serpentine gives rise to two series, the Nipe and Rosario. The Nipe is the only true Laterite soil on the island and has been correlated with the Nipe soil of Cuba. The Rosario is a skeletal Lateritic soil formed on the steeper sides of the serpentine ridge. Apparently, the Nipe Laterite was formed on a level to a rolling position on top of the formation, under an average annual rainfall of 82 inches and a vegetation of tropical trees and brush. Because of its high content of iron, in the form of limonite and averaging about 82 percent, it is considered a nonagricultural soil. The top 4 inches consist of dark reddish-brown friable porous clay with high quantities of organic matter. From the first 4 inches of topsoil downward, there is very little change in color and in chemical and physical characteristics.

The bedrock is often 20 feet deep and the depth very variable, as the serpentine has weathered in pockets. A typical iron hardpan or crust is present at variable depths from the surface depending on the amount of erosion that has taken place. In some instances the crust is exposed on the surface, while in others it may be 16 to 20 inches from the surface and about 4 to 8 inches deep. Many concretions are present scattered throughout the profile. This limonite consists of concretions varying from a few inches to 2 or 3 feet in diameter. Underneath this crust, which in some places is exposed at the surface, is a uniform mass of highly colloidal, friable clay varying in depths from 2 to 15 or 20 feet, and resting abruptly on the serpentine rock.

It is often thought that soils in Puerto Rico are well protected by a heavy tropical vegetation. Because of the density of population practically all the land is in farm land and in the interior mountainous areas of the island very steep and naturally shallow soils are cultivated to subsistence crops. There is a large percentage of idle land, which gives the impression of being completely abandoned; but this type of land is merely "resting" and will be idle for a period of years until the native vegetation builds it up and restores part of its lost productivity. This land will then be put back into cultivation under a year-round growing basis. In such circumstances, created by the steep slopes (60 and 70 percent), high rainfall and type of cultivation, there is no doubt as to the severity of erosion that takes place. The cycle is repeated over and over, but each time its productive period becomes shorter until finally the land must be entirely abandoned.

The main soil series found on the areas that have been worked are: Mucara, Catalina, Cialitos, Descalabrado, Cayagua, Panduras, Juncos, Jacana, and Coamo. Many others have been mapped, but those mentioned are the most important in extent, erosion, and moisture control requirements.

Mucara is an upland, skeletal soil found on steep to very steep slopes. The normal soil has about 4 inches

[1] Assistant soil technologist, Soil Conservation Service, San Juan, P. R.

of brown to grayish-brown topsoil underlain by a yellowish-brown silty subsoil with many angular fragments of rock present. It rests on volcanic tuffs and ashes found at depths of 6 to 26 inches. This soil is used mostly for tobacco and minor crops, namely, sweet potatoes, pigeon peas, cowpeas, and beans. With a year-round growing season, it is not an uncommon practice to raise three different crops on a field in 1 year, and never less than two crops. On slopes of 40 to 60 percent, under intensive plowing and cultivation, it is not long before the subsoil is plowed up and mixed with the topsoil.

The Descalabrado series can be considered as a Mucara soil that has been developed under lower rainfall conditions from a similar kind of parent material except that in some instances it is partly calcareous due to the presence of limestone streaks running through it. Jacana is a soil associated with the Descalabrado and found in the foothills. It has a darker, deeper, and heavier topsoil over a yellowish-brown silty clay. Its topography is smoother and the soil itself may be 3 feet in depth to the tuffaceous parent material. Juncos corresponds to the Jacana, but is found in association with the Mucara series where rainfall is higher.

The Panduras and Cayagua series are derived from quartz diorite granite. Panduras is a skeletal soil having a dark gray-brown coarsely granular surface and lighter colored subsoil with no B horizon development and many large quartz diorite granite boulders present. It very seldom is over 6 inches deep down to rotten granite.

The Cayagua series consists of about 4 to 6 inches of light gray-brown gritty sandy clay loam over 10 to 16 inches of yellowish, more compact sandy clay resting on rotten granite. This soil was classified with the gray-brown Podzolic group.

Catalina is one of the most extensive soil series of the island, and has attracted great attention during recent studies made by J. A. Bonnett of the Agricultural Experiment Station at Rio Piedras, especially with regard to the laterization process as related to chemical, physical, and mineralogical studies of its profile.

The Catalina series is derived from andesitic tuff under a tropical climate with an average rainfall of about 80 inches. The position is variable. Sometimes it is found on top of the ridges on a relatively rolling topography (5- to 15-percent slopes) while again it is found on slopes of 60 to 100 percent. This gives rise to the great variability of depths of the profile to the decomposed bedrock. It ranges from about 4 to 40 feet in depth.

The Cialitos series can be described briefly as a shallower soil, resembling Catalina and derived from shales or finer grained andesitic tuffs. The B horizon is heavier and more compact; fine mottling occurs at about 18 inches, and the total depth to rotten parent material very seldom exceeds 48 inches.

The Coamo series consists of deep alluvial terraces under the Chernozem or Chestnut groups. It has been formed under low rainfall conditions, about 30 to 40 inches of annual precipitation, and by outwashed materials from Descalabrado and Jacana soils. The top 10 inches consists of dark-brown to almost black compact clay which cracks badly during dry weather. The B horizon, 10 to 26 inches, consists of a layer of yellowish-brown clay, grading into stratified sands and gravel. The B horizon is strongly alkaline to calcareous, and lime concretional accumulations are found in the lower deeper strata. Rainfall distribution is very poor in this region, but where water is available Coamo soils produce very good crops.

In making conservation survey maps, we are facing the problem that most of the work has been done on very steep slopes, above 40 percent. The predominant soils on these slopes belong to the Mucara and Descalabrado soils, which are very shallow (skeletal). These soils may vary from 4 inches to about 30 inches in depth to bedrock. As the topsoil is only 4 to 6 inches deep on noneroded soils, as soon as the land is plowed the subsoil is brought up and exposed to erosion. It is obvious that a soil 8 inches deep may have as much as 3 inches of the original topsoil mixed with 5 inches of subsoil; but as the noneroded soil originally had only 4 or 5 inches of surface soil, its degree of erosion varies between classes 2 and 3 as used on the Puerto Rico survey (class 2 erosion on this survey, less than 25 percent of the original topsoil removed; class 3, 25 to 75 percent removed). On the other hand, a soil that has lost the same amount of topsoil but which has 10 or 12 inches of subsoil would fall in the same erosion class but would be more suitable for cropping. Recognition of these differences is very significant in determining use capabilities of land.

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